



Freescal[®] Solutions in **Broadcast:** **FM** (75W, 300W, 600W, kW), **SW**, **DTV**

Li Jun | RFPP Applications Engineer

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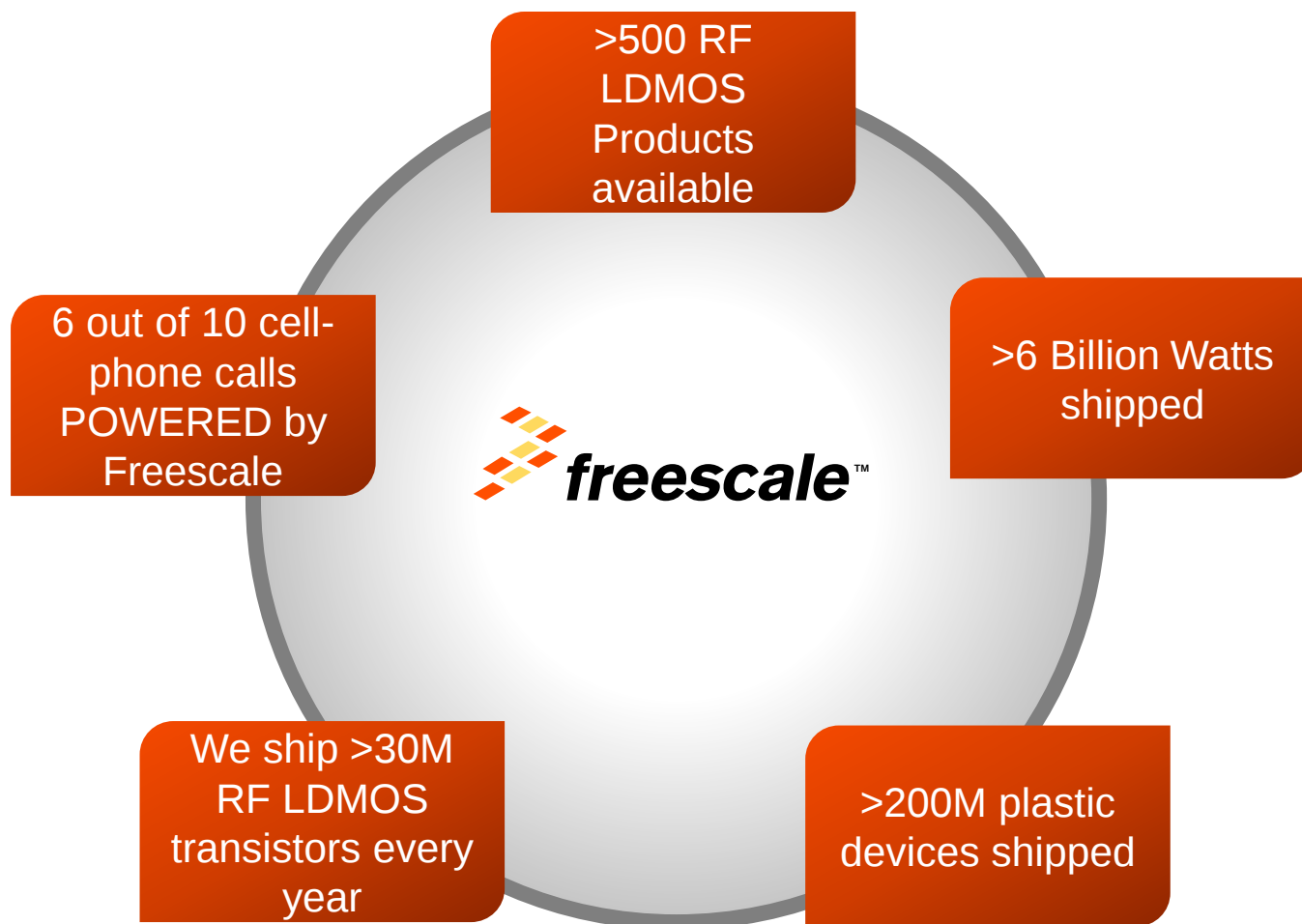


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Freescal RF LDMOS



Broadcast

Market Descriptions

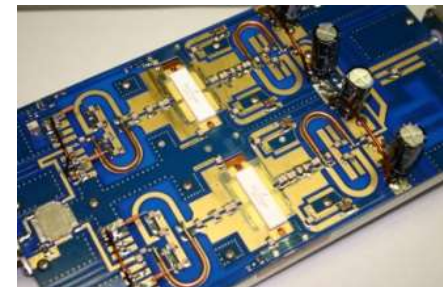
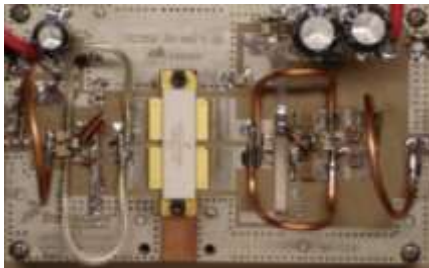
- **FM Radio and HD**
- **VHF TV** (174 to 230 MHz)
- **UHF TV** (470 to 860 MHz)

Key Selling Points

- **High power and high efficiency part for FM and VHF (61K25)**
- **High Ruggedness**

Roadmap Focus

- **CS packaging for better thermals**
- **Doherty**



Broadcast Overview



Competitive Positioning

- **FM Radio:** captured majors accounts worldwide.
- Captured 80% of the market in Americas and 50% in EMEA

Competitive Advantages

- **Rugged E Series**
- **Performance & Breadth of Portfolio**
 - Dedicated, performance-optimized portfolio for all broadcast bands from 2 MHz to 860 MHz
 - **Industry Leading Packages:** Ceramic and Plastic
 - **Thermal Performance**

Broadcast Applications

Analog Television

VHF Analog Television

40 – 88 MHz

175 – 225 MHz

UHF Analog Television

470 – 860 MHz

Radio

Analog

FM

88 – 108 MHz

76-90 MHz (JPN)

Shortwave

2 – 30 MHz

Digital

DAB

174-230 MHz

OFDM

HDFM

88 – 108 MHz

Analog + COFDM

Digital Television (DTV)

VHF 40 - 225 MHz OFDM / VSB

UHF 470 - 860 MHz OFDM / VSB

U.S.A. & Canada
ATSC (VSB)

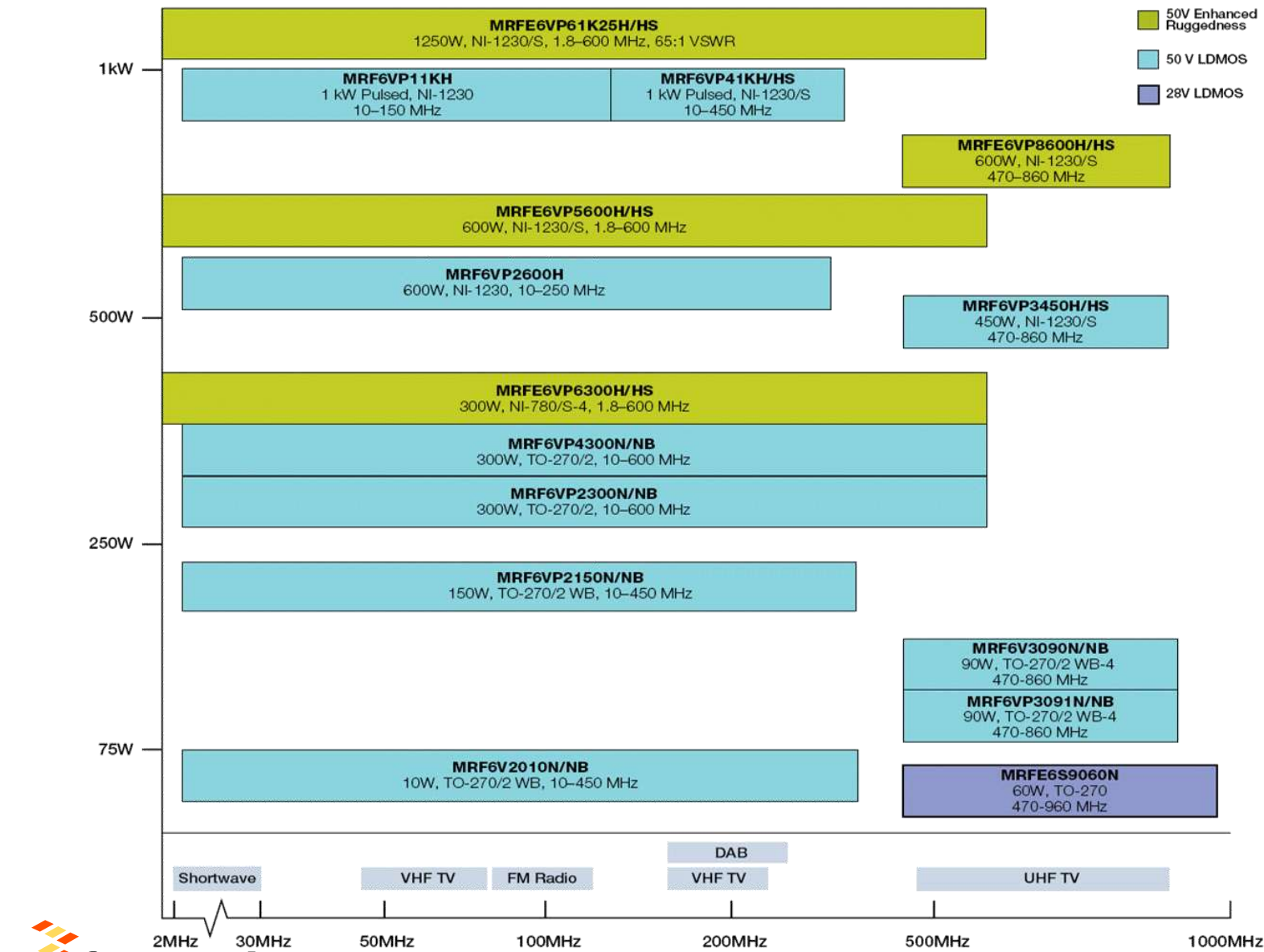
Europe, S America
DVB-T (OFDM)



Freescal RF Power Products For Broadcast

- Most transmitters use multiple devices on “pallets” , multiple pallets are combined into drawers and multiple Drawers are combined into Racks to make up a high power transmitter.
- FSL UHF parts to address all Formats and Power levels
- UHF television devices
 - 450 and 600W peak for conventional Class AB , Envelope Tracking and Doherty for high efficiency applications.
 - 90W Peak for low power or driver applications
- FM Broadcast and VHF Television Devices
 - 10 to 1250W peak to cover all VHF applications
 - 300, 600 and 1250W peak ultra rugged devices

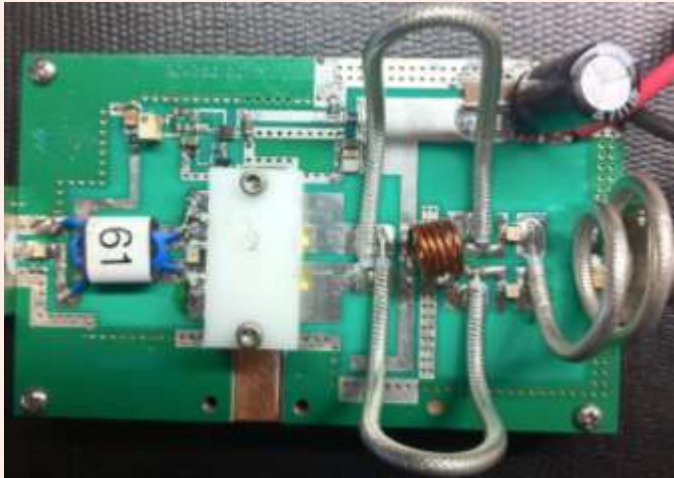
Freescal e RF Power Broadcast Portfolio



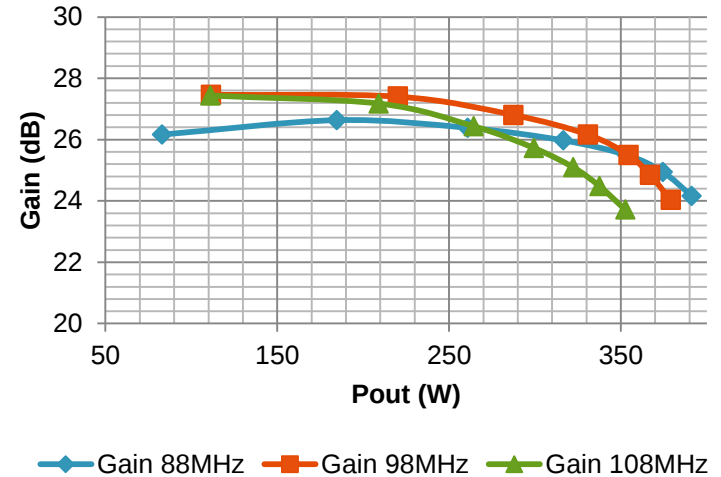
Freescal[®] FM Broadcast Solutions

MRFE6VP6300H FM

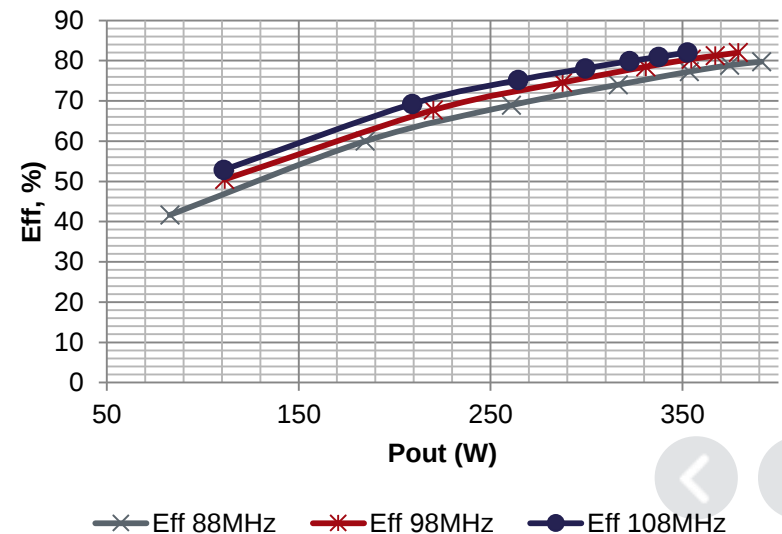
- 88 MHz- 108 MHz
- Output power: >350 W
- Gain: 23.5 ~ 25.5 dB
- Drain efficiency: > 77%



MRFE6VP6300H CW Gain vs Pout



MRFE6VP6300H CW Eff vs Pout



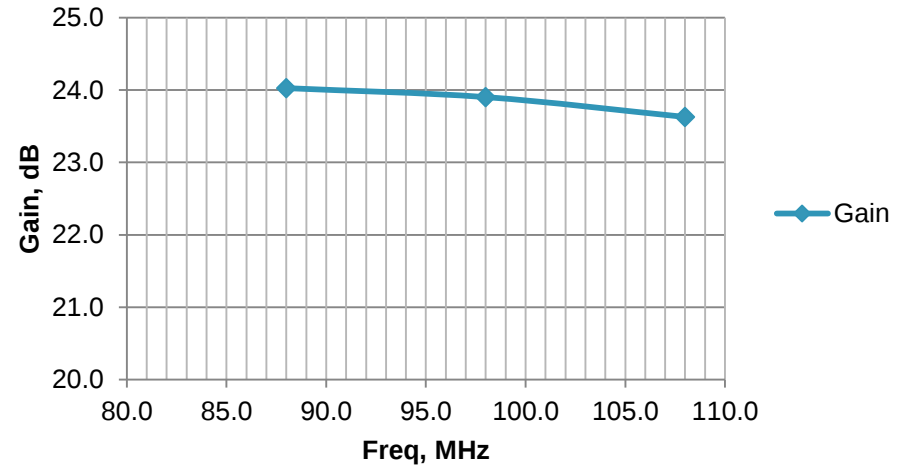
Freescal[®] FM Broadcast Solutions

MRFE6VP5600H FM

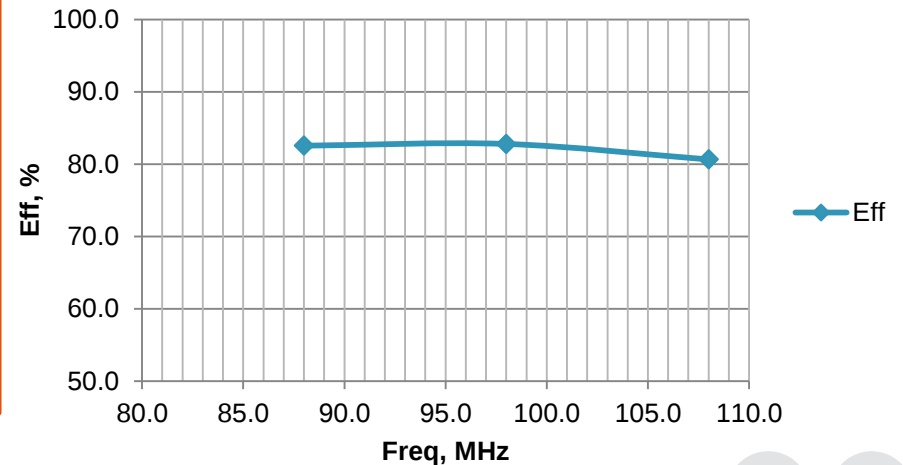
- 88 MHz- 108 MHz
- Output power: > 680 W
- Gain: 23.5 ~ 24 dB
- Drain efficiency: > 80%



5600 FM Performance



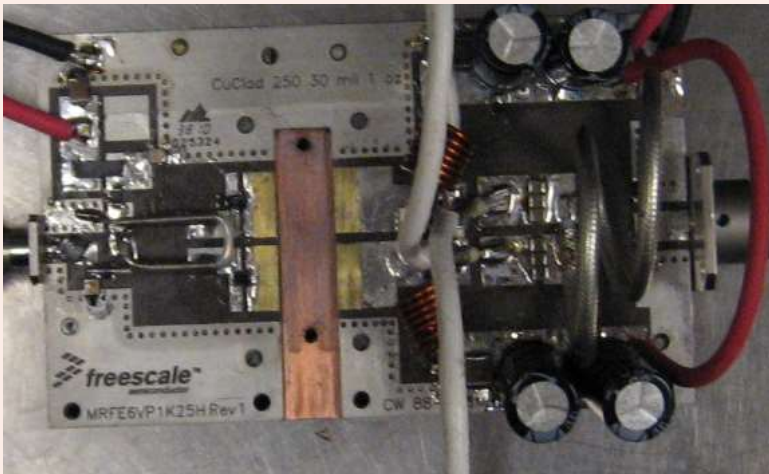
5600 FM Performance



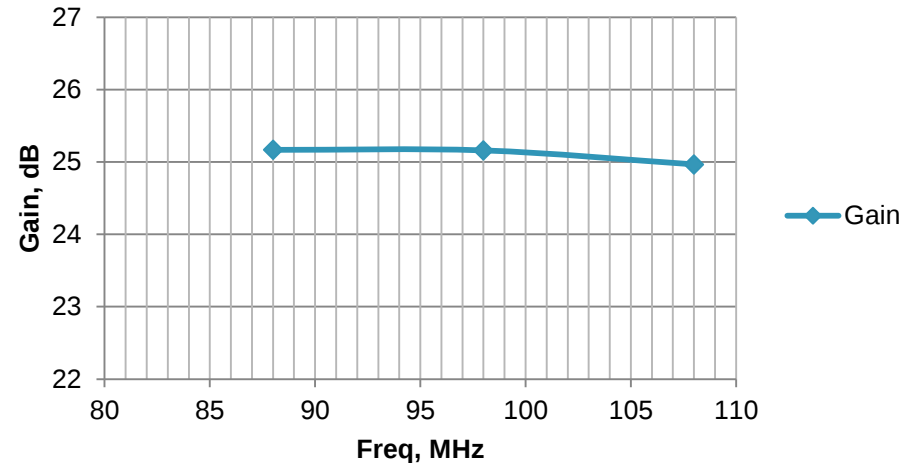
Freescal[®] FM Broadcast Solutions

MRFE6VP61K25H FM

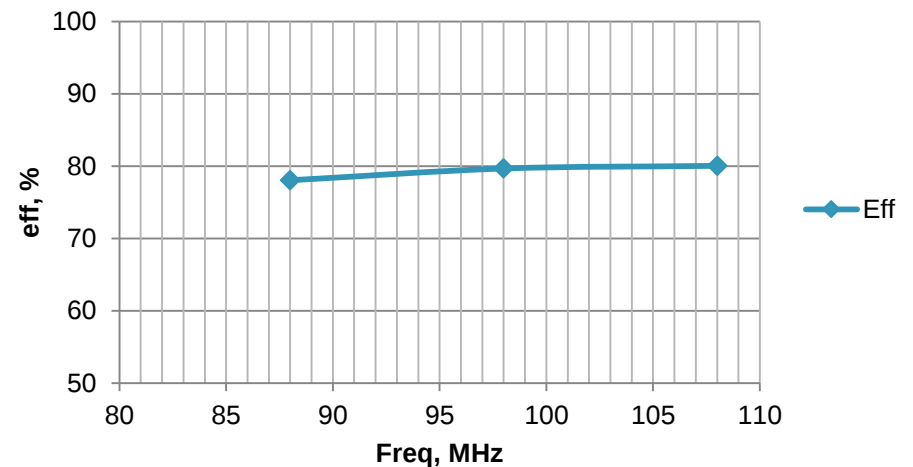
- 88 MHz- 108 MHz
- Output power: >1100 W
- Gain: 24.7 ~ 25.3 dB
- Drain efficiency: > 80 %



61K25 FM Performance



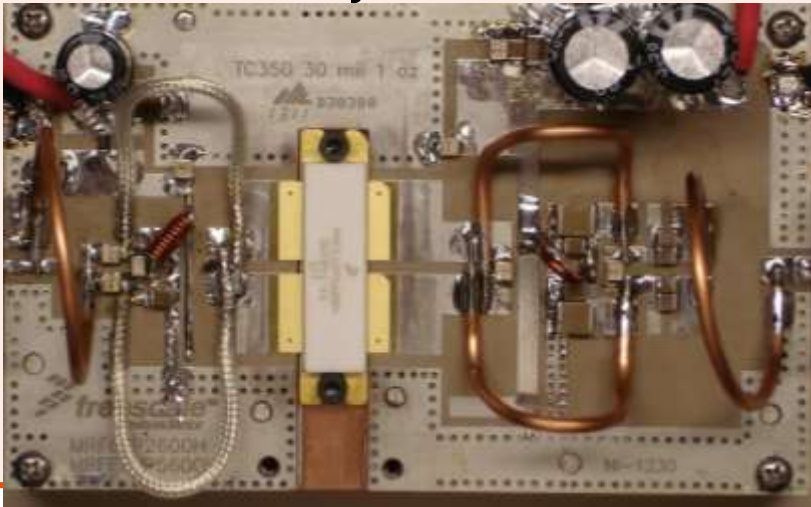
61K25 FM Performance



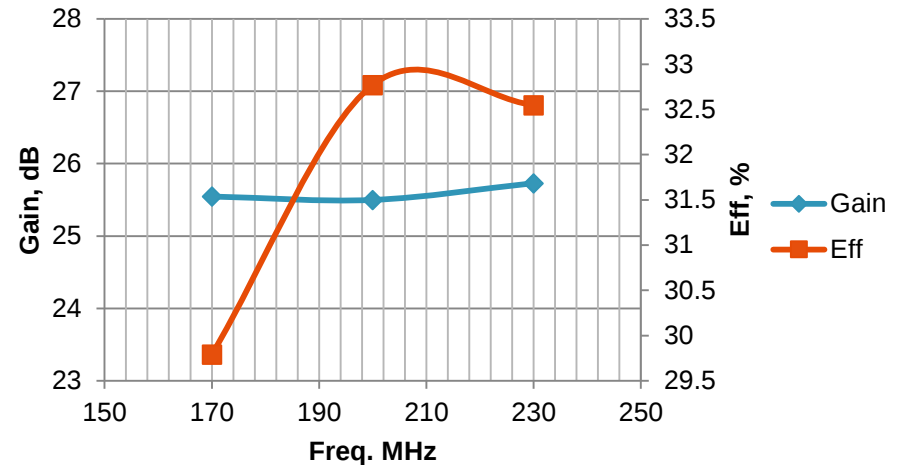
Freescal VHF Broadcast Solutions

MRFE6VP5600H VHF

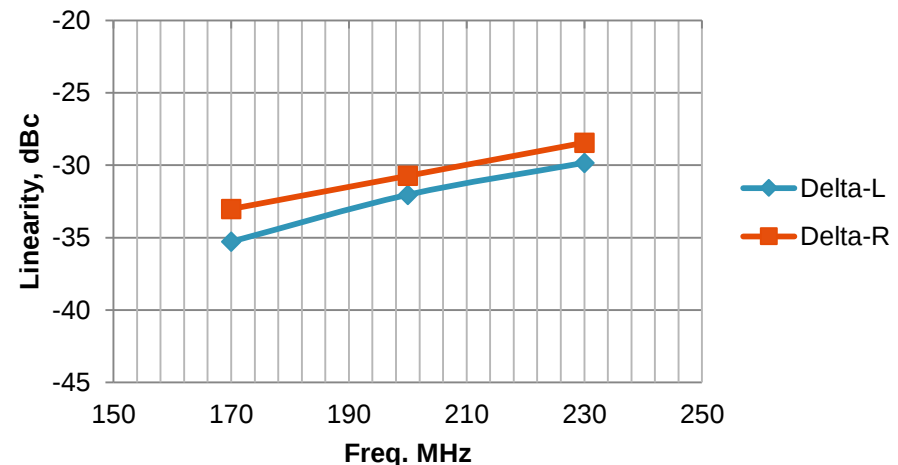
- 170 MHz- 230 MHz
- Output power: 125 W
- Gain: > 24 dB
- Delta marker: < -28 dBc
- Output PAR: > 7.3 dB
- Drain efficiency: > 28%



5600 VHF Performance



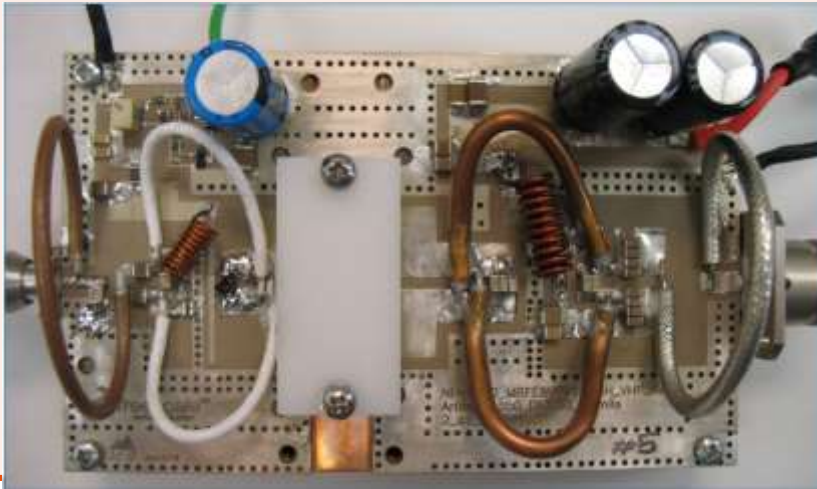
5600 VHF Performance



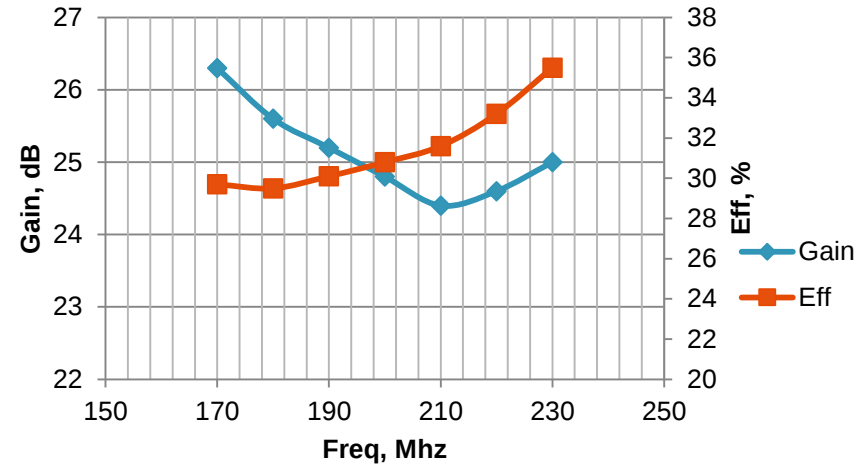
Freescal VHF Broadcast Solutions

MRFE6VP61K25H VHF

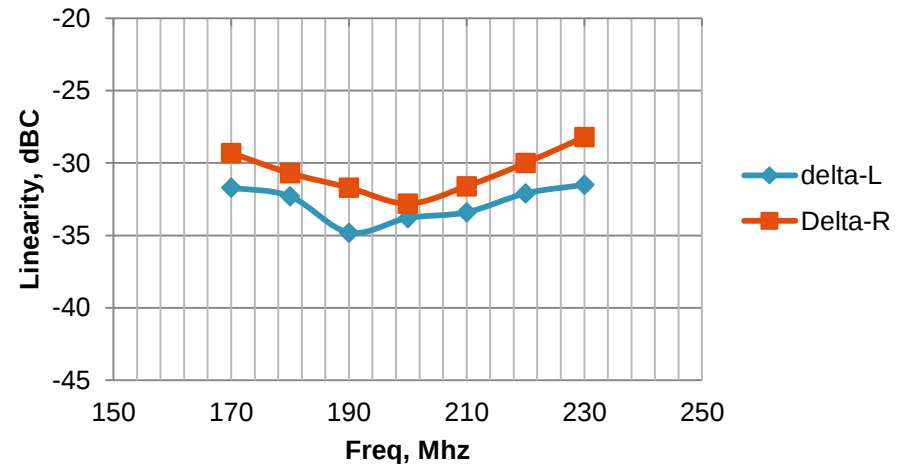
- 170 MHz- 230 MHz
- Output power: 225 W
- Gain: > 24 dB
- Delta marker: < -30 dBc
- Output PAR: > 8.3 dB
- Drain efficiency: > 29%



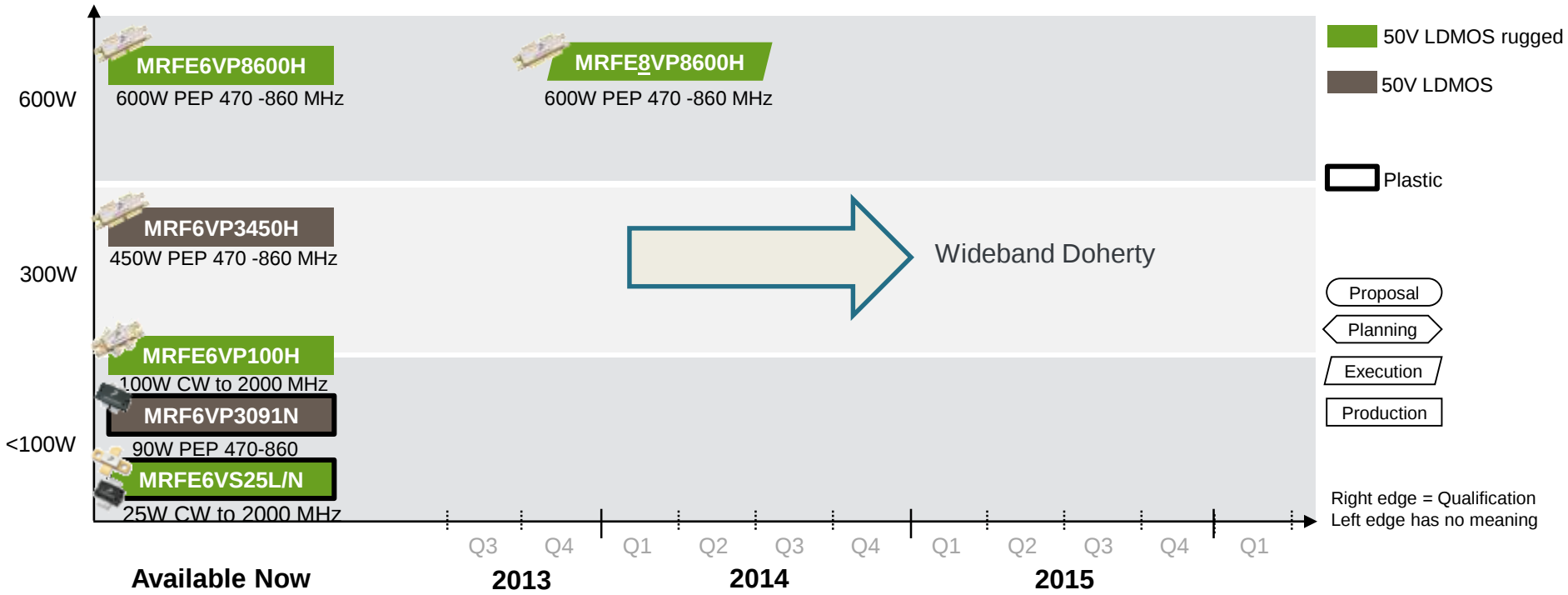
61k25 VHF Performance



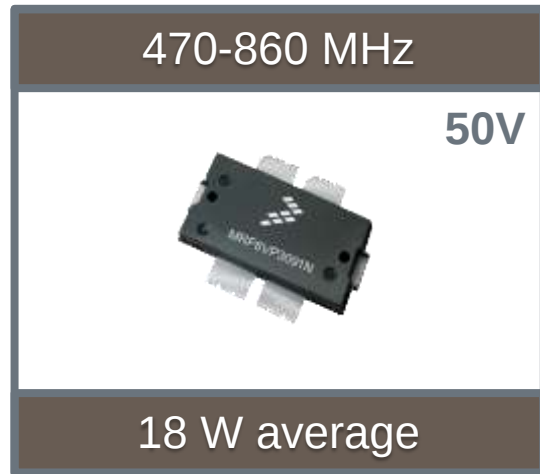
61k25 VHF Performance



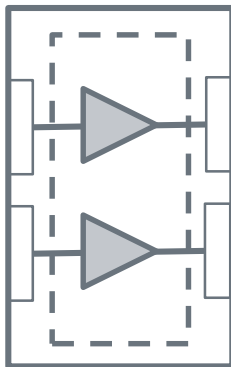
UHF Broadcast Roadmap



MRF6VP3091N: 90W PEP Driver Transistor for UHF Broadcast Applications



- Input pre-matched
- 22 dB gain at 860 MHz
- 28.5 % efficiency
- Housed in a TO-270 plastic package
- Rugged: 10:1 VSWR



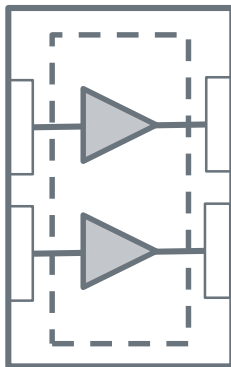
Available Reference Circuits

- 470- 860 MHz Class AB

MRF6VP3450H: 450W PEP Transistor for UHF Broadcast Applications



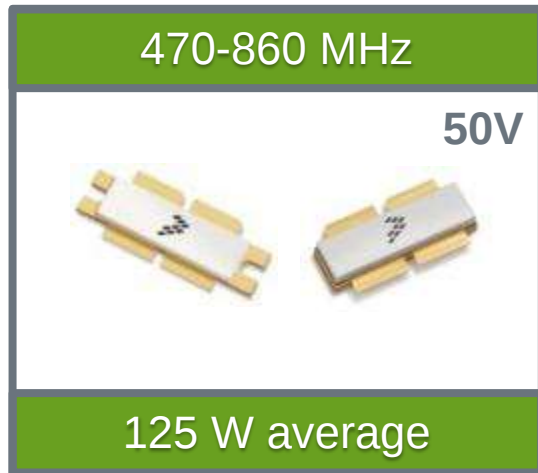
- Input pre-matched
- 22.5 dB gain at 860 MHz
- 28% efficiency
- Housed in an NI-1230 air-cavity ceramic package
- Rugged: 10:1 VSWR



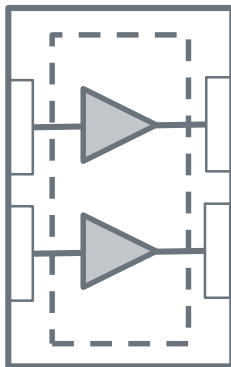
Available Reference Circuits

- 470-860 MHz Class AB
- 786-802 MHz Doherty

MRFE6VP8600H: 600W PEP Transistor for UHF Broadcast Applications



- Input pre-matched
- 19.3 dB gain at 860 MHz
- 30% efficiency
- Housed in an NI-1230 air-cavity ceramic package
- Extreme Ruggedness: handles $>65:1$ VSWR with 3dB overdrive

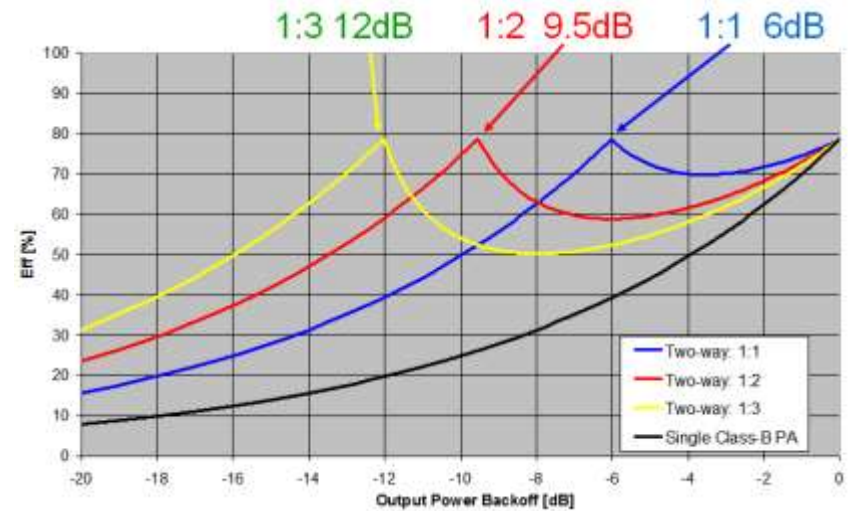
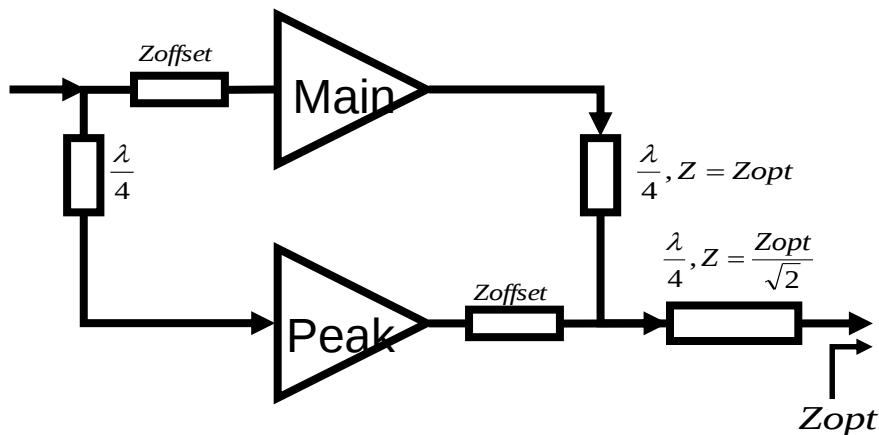


Available Reference Circuits

- 860 MHz (125 W avg)
- 470-860 MHz class AB (125 W avg)
- 470-810 MHz class AB compact (125 W avg)
- 470-560 MHz Doherty (1 transistor, 120 W avg)
- 600-650 MHz Doherty (1 transistors, 120 W avg)
- 650-700 MHz Doherty (1 transistors, 120 W avg)
- 700-750 MHz Doherty (1 transistor, 120 avg)
- 750-850 MHz Doherty (1 transistor, 120 W avg)

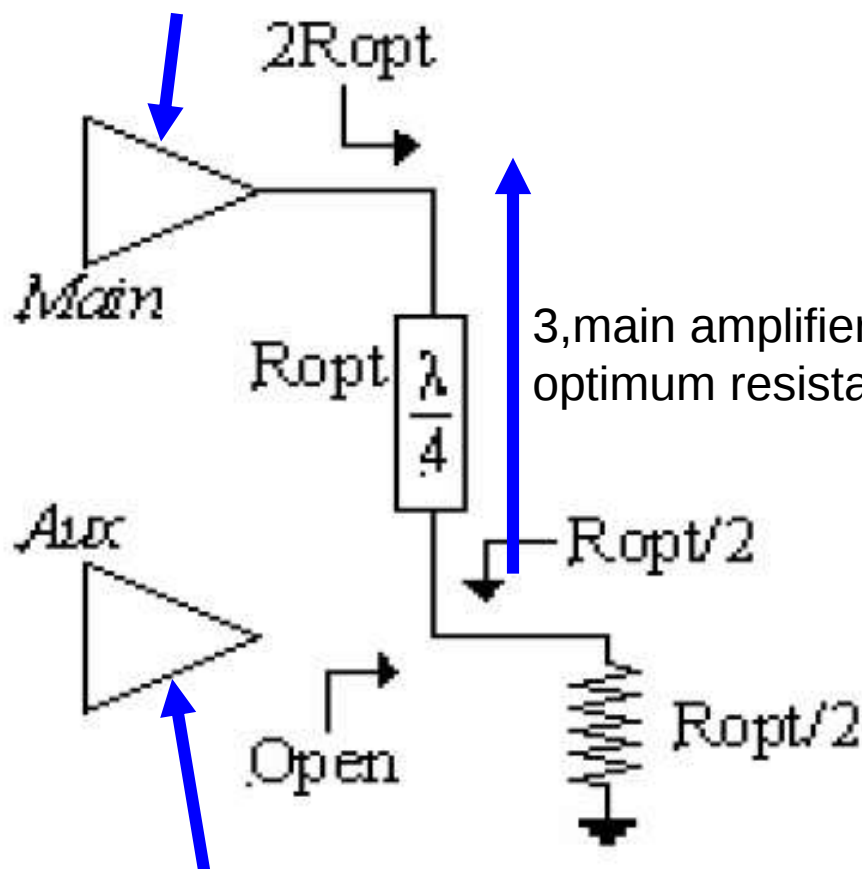
Doherty Design with Freescale LDMOS

1. Low level output signals
2. High level output signals
3. Medium level output signals



Stage 1 Low Level Output Power

2, The total input signal is received by the main amplifier

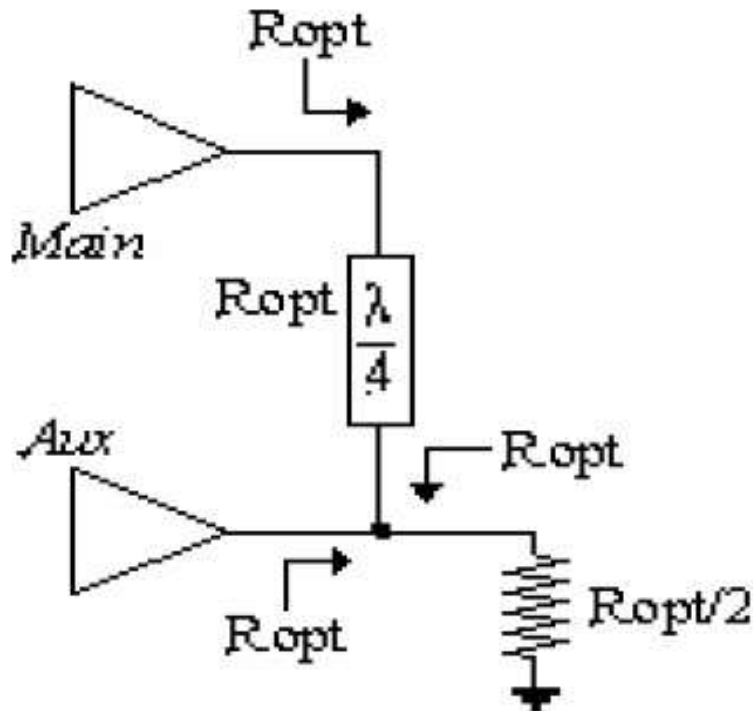


1. The peak amplifier is turned off.

3, main amplifier to see twice the optimum resistance

4, The high output impedance leads to premature saturation of the main amplifier while the current has reached only half of its maximum value. Since the voltage has reached its maximum value, the system works with maximum efficiency though it does not deliver the maximum power.

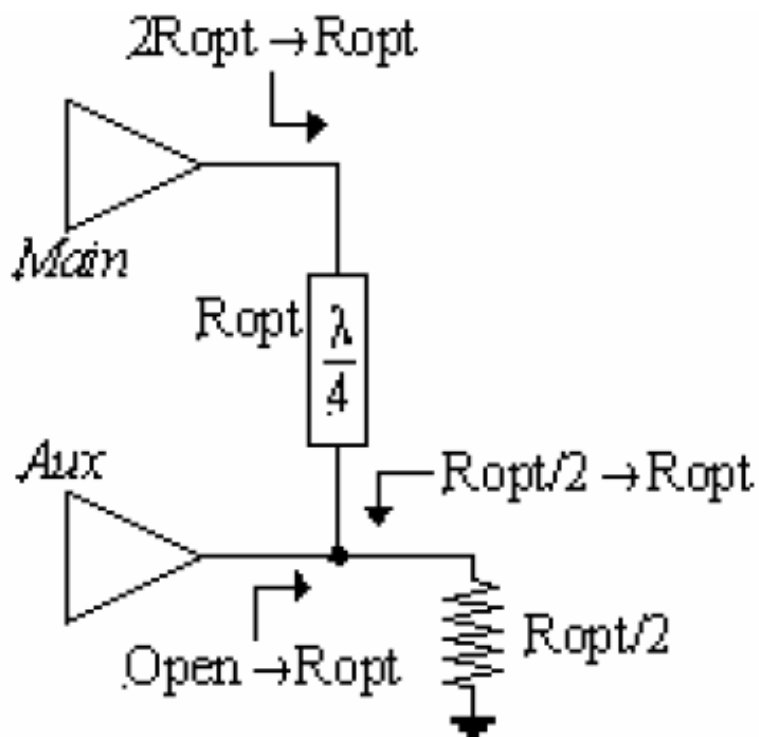
Stage 3 High Level Output Power



As the input level increases, the load power keeps increasing until the peak amplifier saturates.

Once the maximum level is reached, both the main and the peak amplifier see an optimum resistance, R_{opt} equal to the characteristic impedance of the quarter wave transmission line.

Stage 2 Medium Level Output Power



As soon as the main amplifier saturates, suitable biasing enables the peak amplifier to turn on, resulting in the flow of auxiliary current.

According to the active load pull technique, the increase in the peak current increases the impedance, R_{out} , seen by the quarter wave transmission line. Hence increase in R_{out} results in decrease of the impedance seen by the main amplifier.

This cause the main amplifier output voltage to remain constant without getting into saturation and increasing the output current from the main amplifier.

Design Process

- Single LDMOS Class AB PA (Z_{opt} & $2Z_{opt}$ matching)
- Optimum Length of Offset Line (Get higher output impedance seen at the output junction, Reduce Leakage Current)
- Combiner & Splitter
- Optimum gate bias of peak amplifier (to enhance efficiency)

Impedance Design for Doherty Amplifier

- α is defined as P_{main}/P_{out} ,
For symmetrical Doherty amplifier,
 $\alpha = 1/2$.

- So the max efficiency is at -6 dB backoff.

$$\alpha[\text{dB}] = 10\log\left(\frac{P_{\alpha}}{P_{\max}}\right) = 10\log(\alpha^2) = -6\text{dB}$$

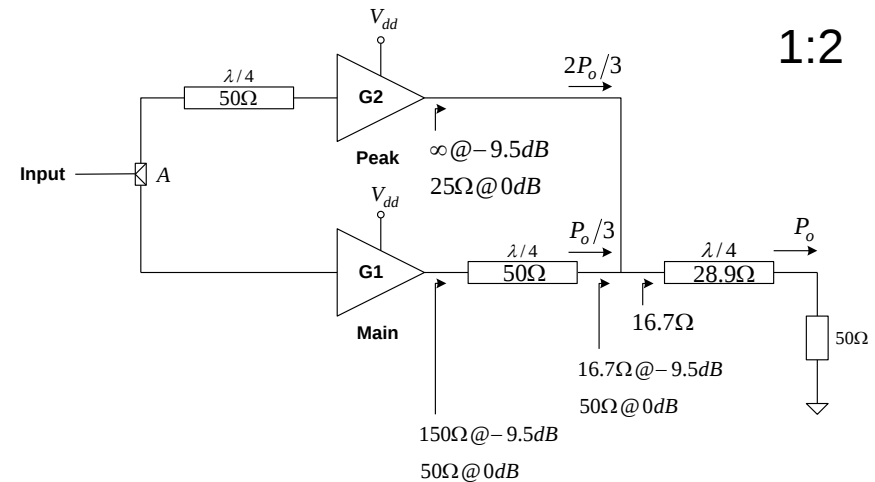
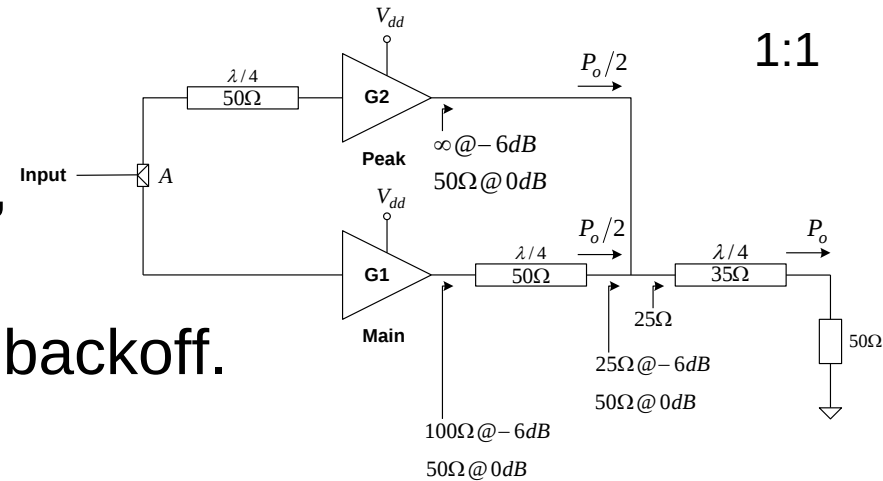
- The load impedance is

$$R = \alpha Z_0 = 25\ \Omega$$

- $\lambda/4$ line impedance will be

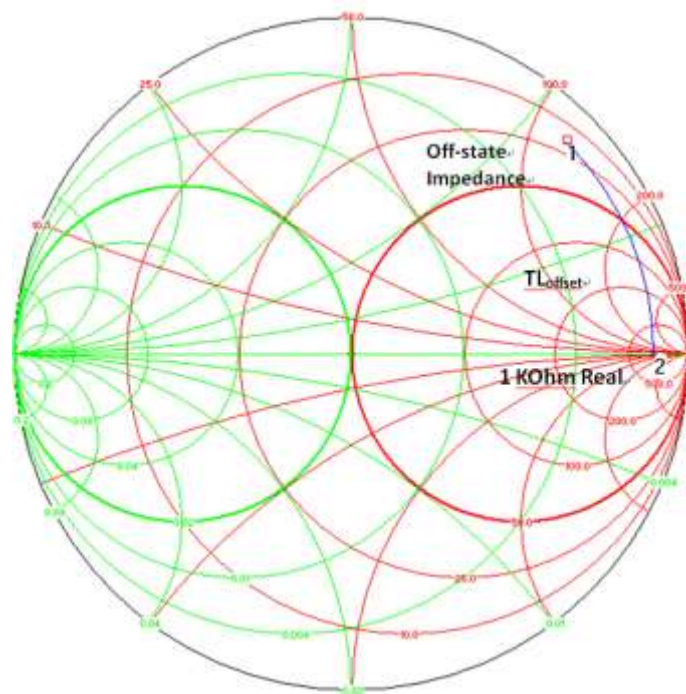
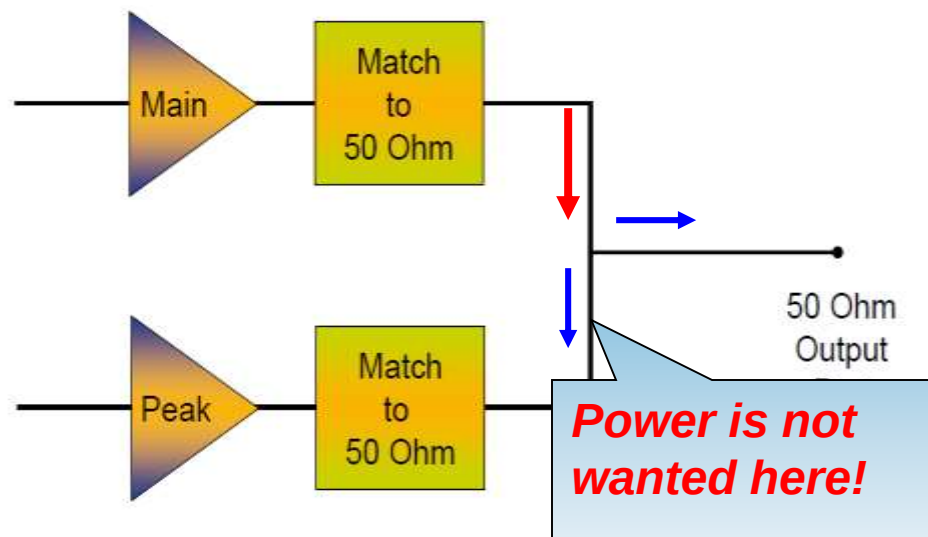
$$Z_{line} = \sqrt{R * Z_0} = \sqrt{25 * 50} = 35\ \Omega$$

- This calculation is also valid for asymmetrical Doherty amplifier.

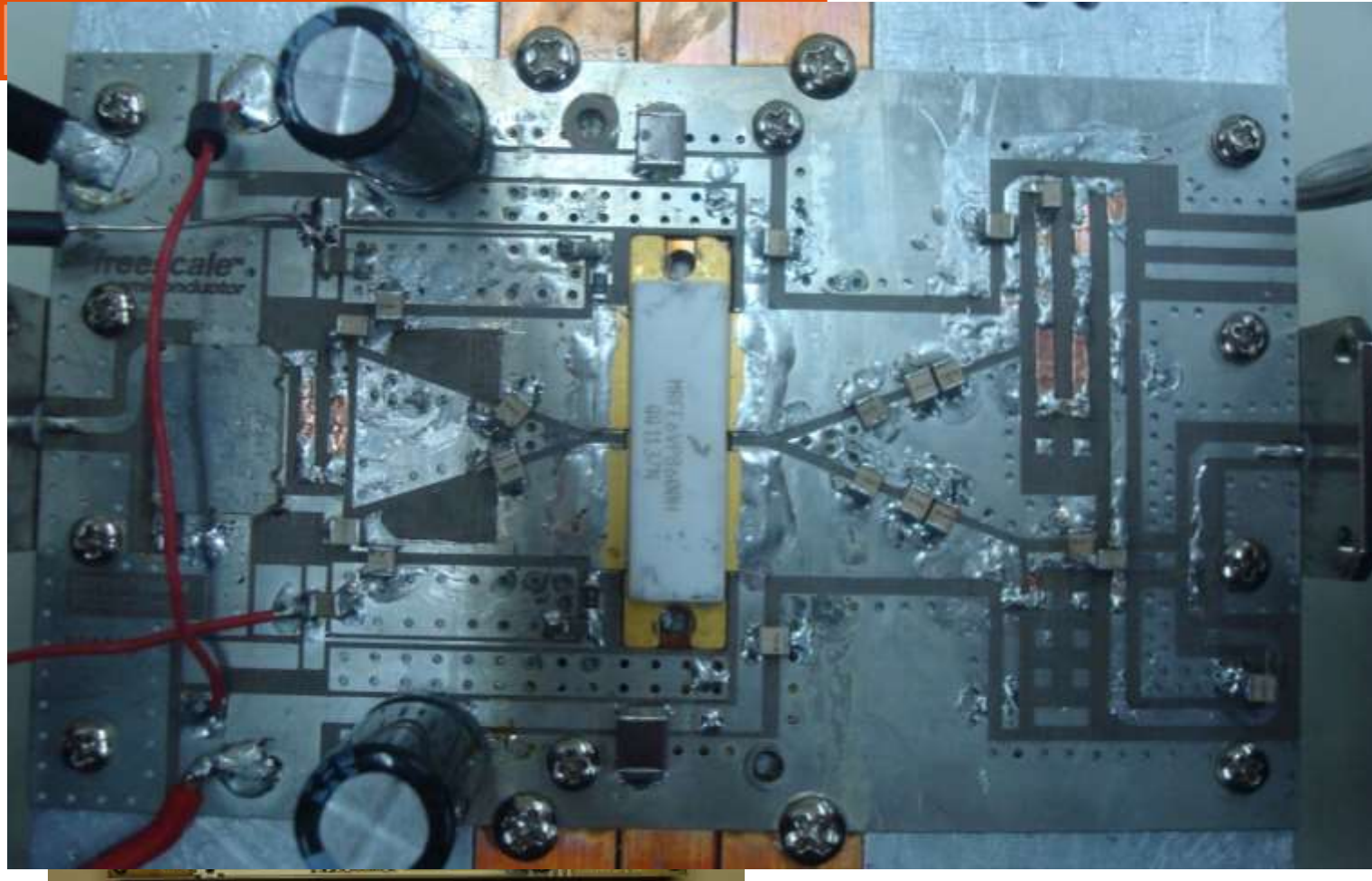


Offset Line Design

- Why Offset Line??
 - When only the main amplifier is active, we need to avoid any power "leaks" into the peak amplifier. If it does happen, we will loss main amp power, and thus the efficiency!



Freescal Broadcast Doherty Solutions



Freescal Broadcast Doherty Solutions

MRFE6VP8600H 1up Doherty

- 470 MHz- 560 MHz
- Output power: 120 W
- Gain: > 19 dB
- corrected delta marker: < -40 dBc
- corrected output PAR: > 8.3 dB
- Drain efficiency: 42%~ 45%

MRFE6VP8600H 1up Doherty

- 600 MHz- 650 MHz
- Output power: 120 W
- Gain: > 19 dB
- corrected delta marker: < -40 dBc
- corrected output PAR: > 8.5 dB
- Drain efficiency: 41%~ 44%

Freescal Broadcast Doherty Solutions

MRFE6VP8600H 1up Doherty

- 650 MHz- 700 MHz
- Output power: 120 W
- Gain: > 18 dB
- corrected delta marker: < -40 dBc
- corrected output PAR: > 8.3 dB
- Drain efficiency: 42%~ 45%

MRFE6VP8600H 1up Doherty

- 700 MHz- 750 MHz
- Output power: 120 W
- Gain: > 16 dB
- corrected delta marker: < -40 dBc
- corrected output PAR: > 8.5 dB
- Drain efficiency: 39%~ 44%

Freescal Broadcast Doherty Solutions

MRFE6VP8600H 1up Doherty

- 750 MHz- 800 MHz
- Output power: 120 W
- Gain: > 17 dB
- corrected delta marker: < -40 dBc
- corrected output PAR: > 8.3 dB
- Drain efficiency: 41%~ 47%

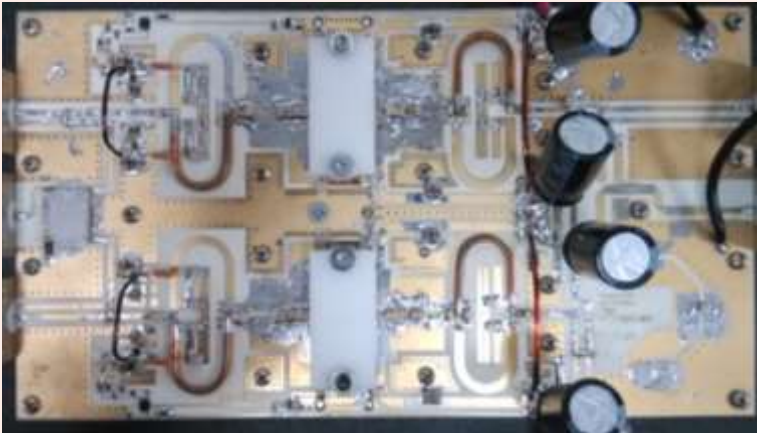
All Doherty board has same PCB layout.

Different BOM and offset line for different band.

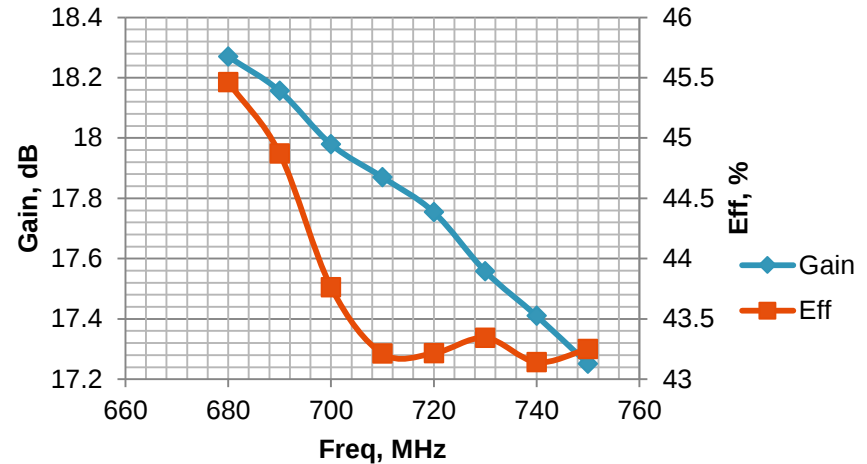
Freescal Broadcast Doherty Solutions

MRFE6VP8600H Dual Device

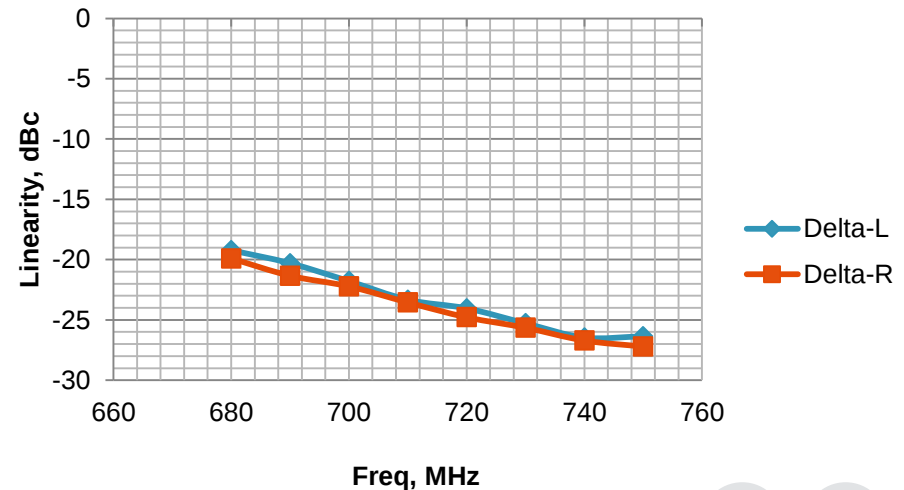
- 678 MHz~ 750 MHz
- Output power: 240 W
- Gain: > 17.2 dB
- Delta marker: < -19 dBc
- Output PAR: > 7.3 dB
- Drain efficiency: 43%~ 45%



6VP8600 680-750 MHz Doherty



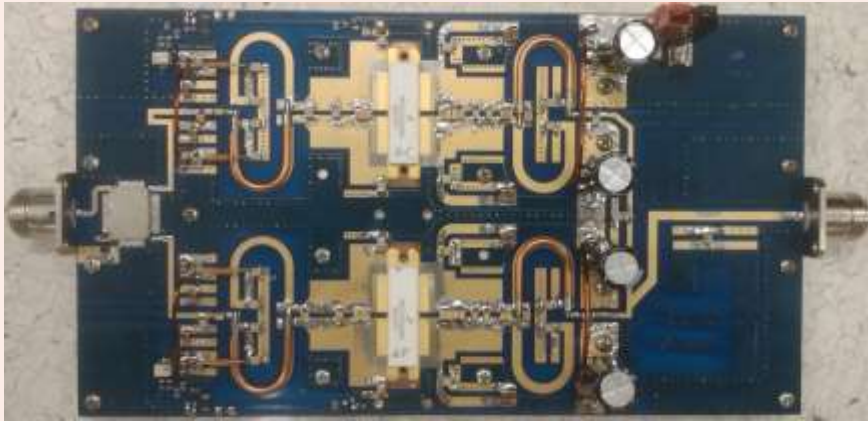
6VP8600 680-750 MHz Doherty



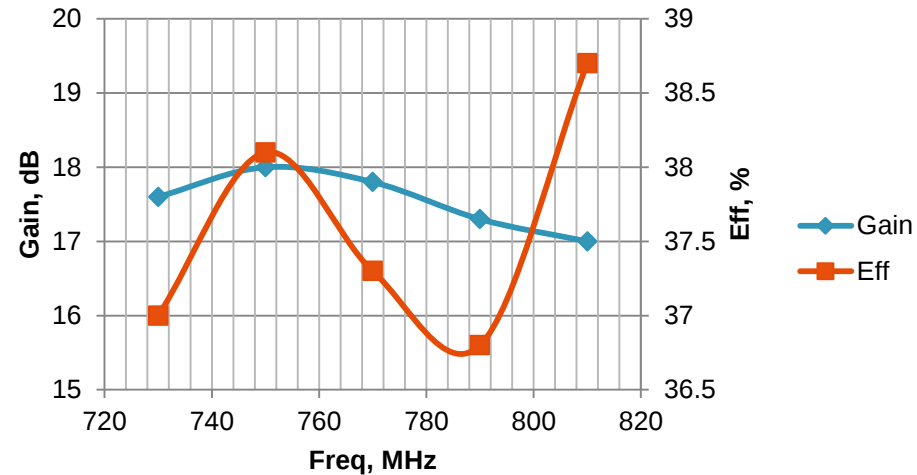
Freescal Broadcast Doherty Solutions

MRFE6VP8600H Dual Device

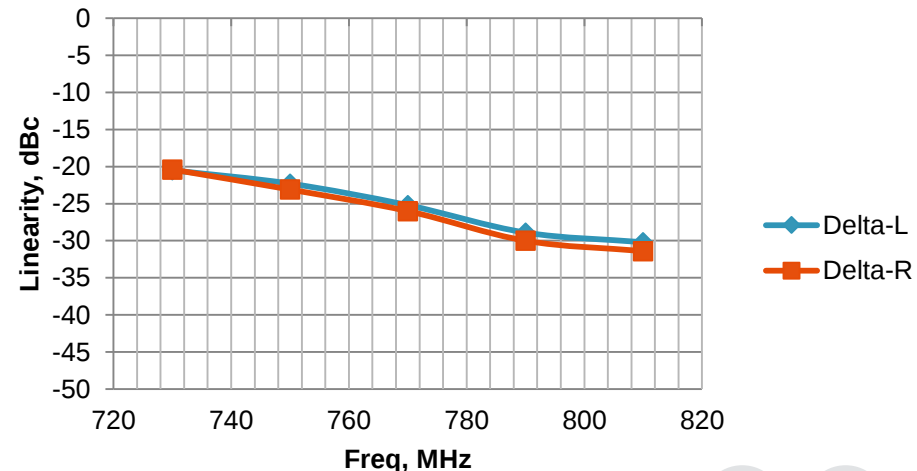
- 730 MHz~ 810 MHz
- Output power: 240 W
- Gain: > 16.5 dB
- Delta marker: < -20 dBc
- Output PAR: > 7.0 dB
- Drain efficiency: >37%



6VP8600 730-810 MHz Doherty



6VP8600 730-810 MHz Doherty

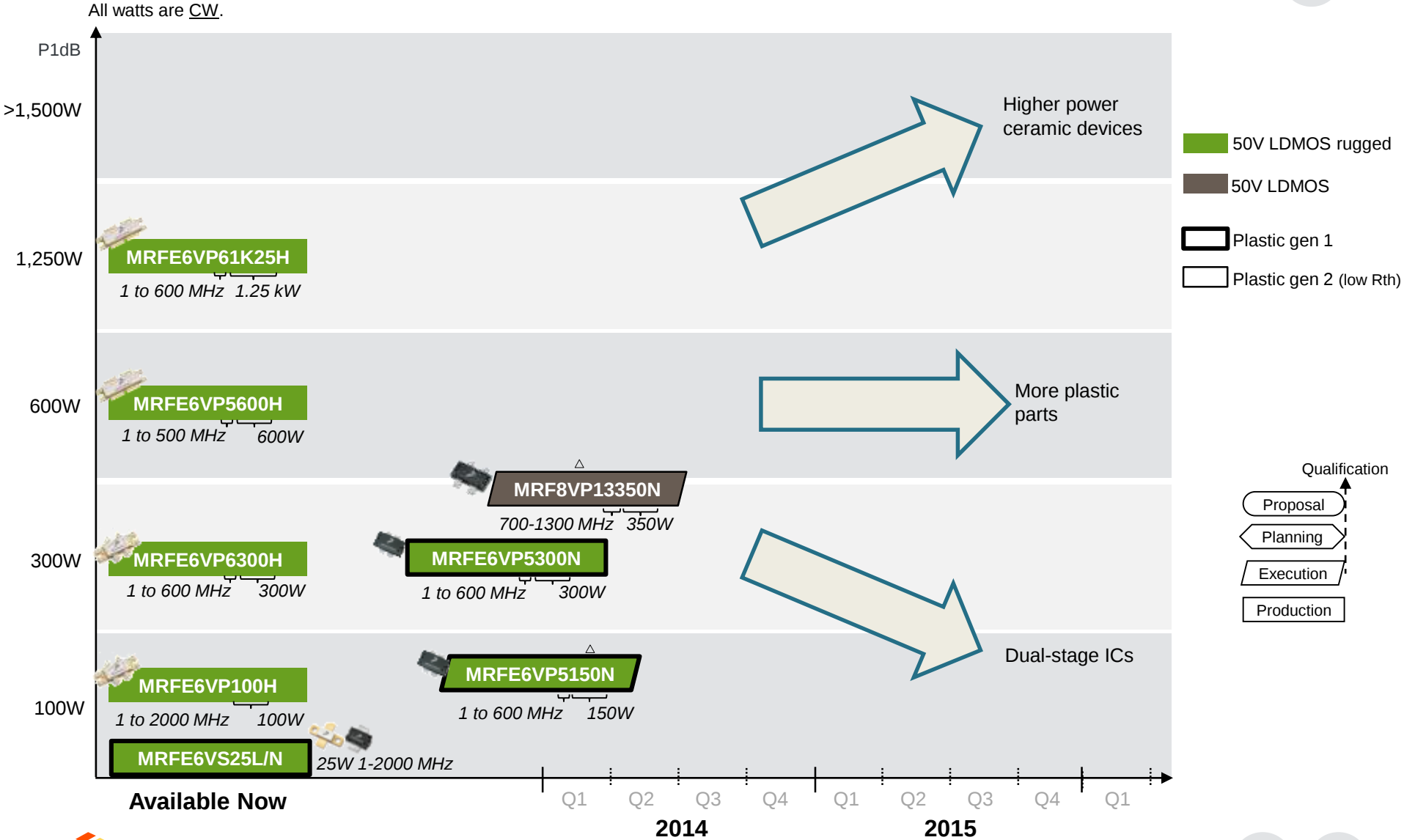


Industrial, Scientific, Medical (ISM)

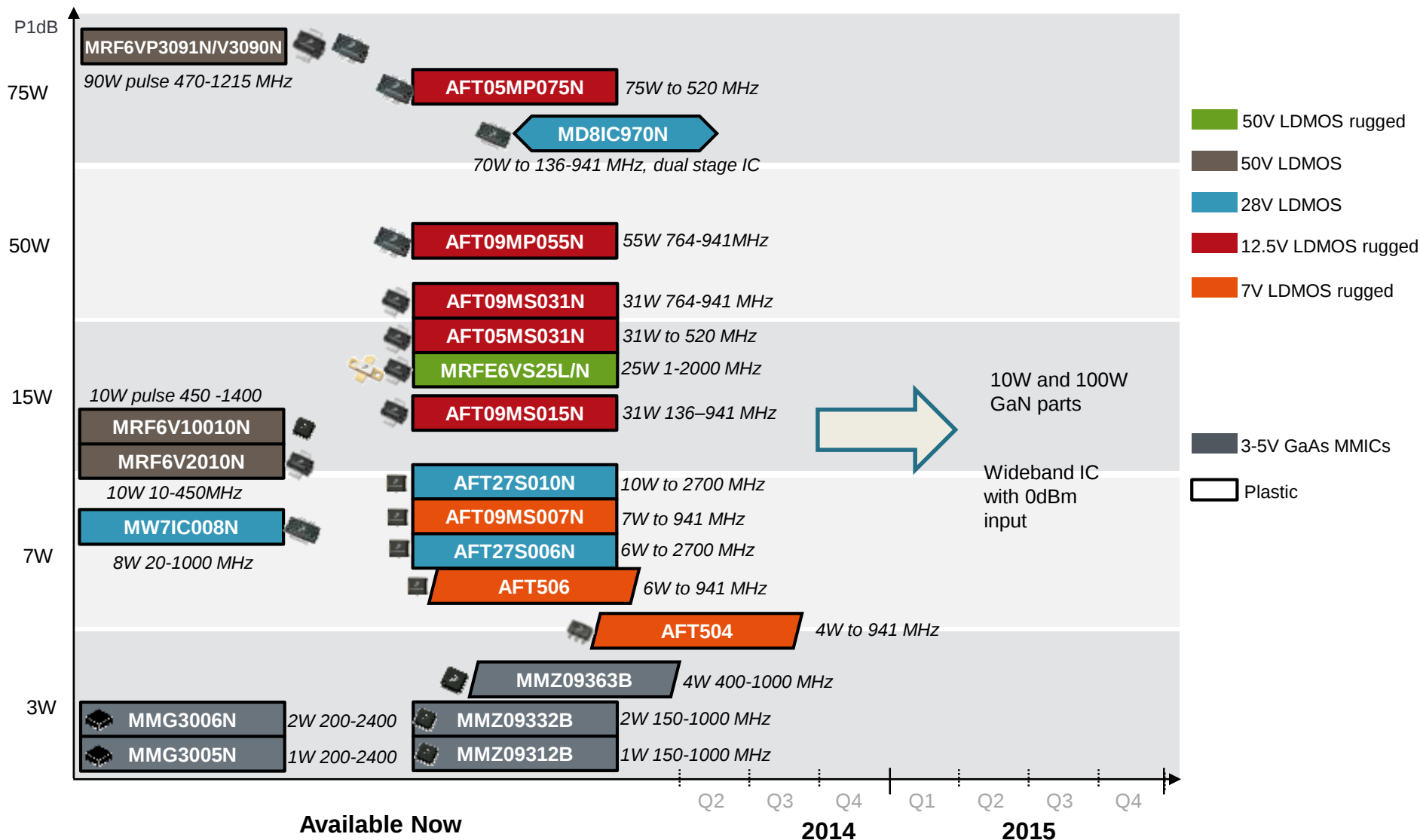
- CO2 Laser
- Plasma Generation
- Synchrotron
- Magnetic Resonance Imaging (MRI)



ISM Roadmap – Final Stage Transistors



ISM Roadmap – Drivers



Freescal LDMOS Advantages for ISM

- Common theme on most ISM applications is RF Load is variable and places stress on amplifier components.
- Ruggedness is not an option.. **It Is A Requirement!**
- Outstanding ruggedness improves system reliability and flexibility.
- Enhanced ESD allows device Class C operation.

What is Ruggedness?

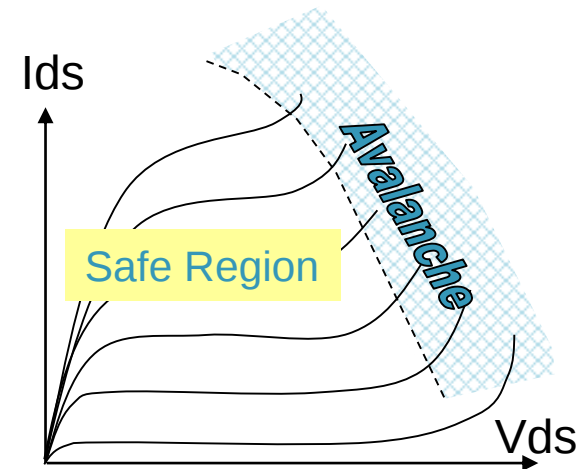
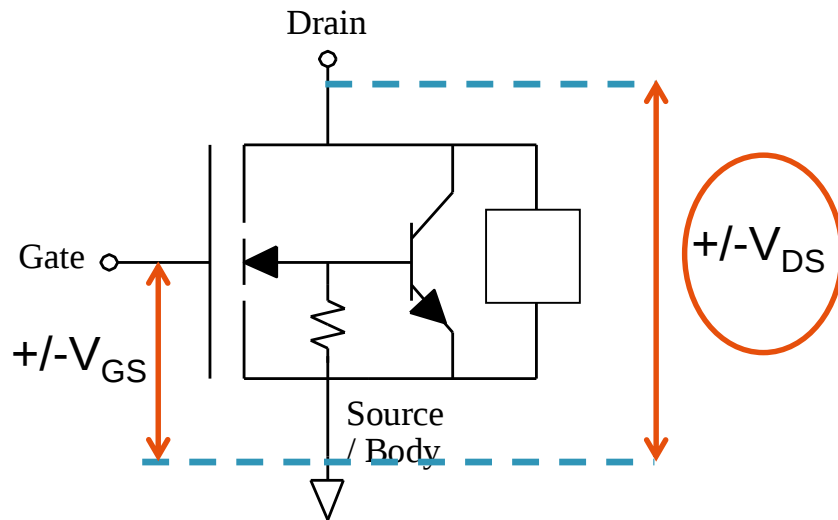
- In customer applications, transistors contained within the RF power amplifier are subject to high internal voltage stresses arising from operation with wide bandwidth input signals.
- The ability for the transistors to sustain these high stresses is defined in terms of ruggedness.
- When the stresses are not sustained by the transistor, a ruggedness failure occurs with permanent damage to the transistor.
- Failures can be “soft” with a loss in performance ... output power, higher gate current and so on, or hard / destructive.

Freescal Ruggedness Definition

- Ruggedness is the ability of the PA to withstand a short term (nano – micro seconds) increase in electrical stress.
 - Examples: Overvoltage, Transients, ESD, Oscillations
- Overall ruggedness is determined by three main categories:
 1. Die – Device Ruggedness
 2. PCB Circuit – Application Ruggedness
 3. System – Input signals, power levels, power supply

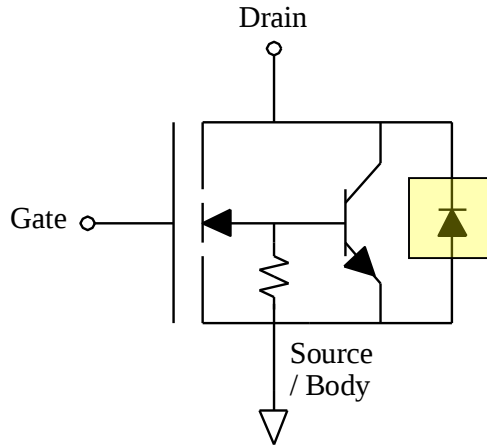
Device Ruggedness and EOS (Electrical Over Stress)

- EOS occurs when the maximum voltage potentials have been exceeded across any two terminals of the device inducing device breakdown resulting in excessive currents
- In addition there are combinations of V_{GS} and V_{DS} that can place the device drain into avalanche and lead to EOS events
- Failures may occur in either steady state or transient operation

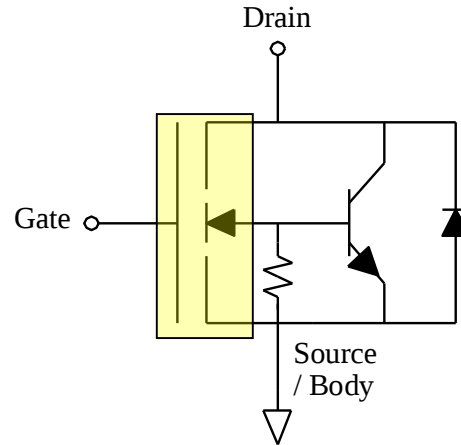


Mechanism of Ruggedness Failure

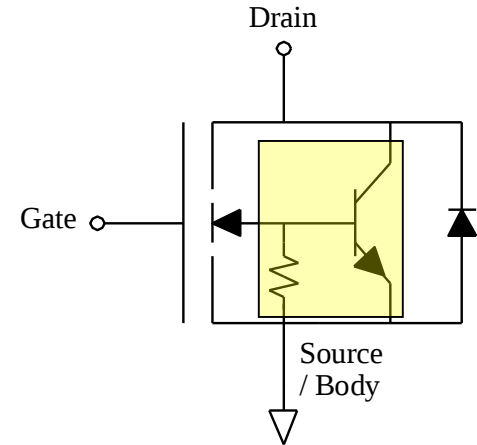
- There are 3 scenarios within the FET for high currents on the drain interconnect structures.



vertical avalanche



lateral avalanche



parasitic BJT

- By design Freescale avoids the vertical avalanche condition.
- This leaves lateral avalanche and parasitic BJT for which the lateral avalanche is a pre-condition.

Why Freescale is Better for Ruggedness?

- FSL E series devices are more rugged than competing LDMOS devices.
- Power levels 25W to beyond 1200W CW
- High efficiency & Low thermal resistance.
- Tested to handle rated VSWR with:
 - @ Full Peak Power, with 3dB input overdrive AND
 - At least 65:1 VSWR all phase angles
 - Some devices up to 50% overvoltage simultaneously
- Can handle pulses with fast rise/fall times (as fast as 6ns).
- Rugged parts can be used in many different applications
 - Laser (30-175 MHz)*
 - Broadcast FM (88-108MHz)*
 - Broadcast TV (470-860MHz)*
 - HF Radio (2-30MHz)*
 - Particle Accelerator (200-500MHz)*
 - MRI (64-500MHz)*

Freescalé's High Power Rugged Offering

MRFE6VP6300H/S



- 300W CW at 50V
- 1.8 MHz – 600 MHz
- 25 dB gain at 130 MHz
- 80% efficiency at 130 MHz
- NI-780-4 air cavity ceramic package
- Handles >65:1 VSWR with 3dB overdrive
- Advanced integrated ESD protection provides gate-source voltage range (-6V to +10V) to enhance performance when operating in modes such as Class C.

MRFE6VP5600H/S



- 600W CW at 50V
- 1.8 MHz – 600 MHz
- 24.6 dB gain at 230 MHz
- 75% efficiency at 230 MHz
- NI-1230 air-cavity ceramic package
- Handles >65:1 VSWR with 3dB overdrive
- Advanced integrated ESD protection provides gate-source voltage range (-6V to +10V) to enhance performance when operating in modes such as Class C.

MRFE6VP61K25H/S



- 1250W CW at 50V
- 1.8 MHz – 600 MHz
- 22.9 dB gain at 230 MHz
- 74% efficiency at 230MHz
- NI-1230 air-cavity ceramic package
- Handles >65:1 VSWR with 3dB overdrive
- Advanced integrated ESD protection provides gate-source voltage range (-6V to +10V) to enhance performance when operating in modes such as Class C.

MRFE6VP8600H/S



- 125W Avg/600W PEP at 50V
- 470 MHz – 860 MHz
- 19 dB gain at 860 MHz
- 30% DVB-T efficiency at 860MHz
- NI-1230 air-cavity ceramic package
- Handles >65:1 VSWR with 3dB overdrive
- Advanced integrated ESD protection to enhance performance when operating in high-efficiency modes such as Doherty

Wideband 'E' Series Rugged LDMOS Lineup **Wideband, Wide Frequency Range**

MRFE6VP100H



- > 100W CW P1 dB Output
- Broadband operation to 1000 MHz
- 1- 2000 MHz usable range
- 25 dB Gain @ 500 MHz
- 13 dB Gain @ 2000 MHz
- 30% DVB-T efficiency at 860MHz
- NI-780-4 4 lead air cavity ceramic package
- Handles >65:1 VSWR with 3dB overdrive
- Advanced integrated ESD protection

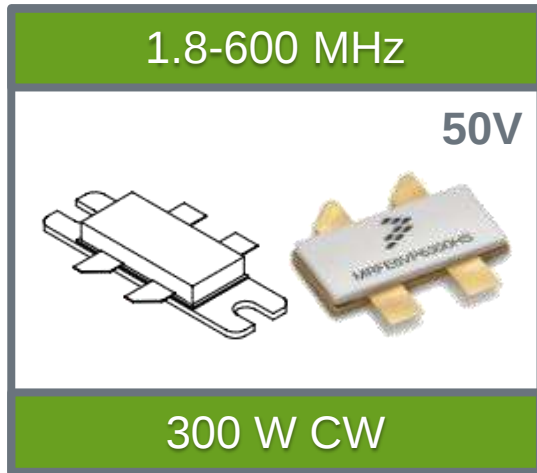
MRFE6VS25N / L



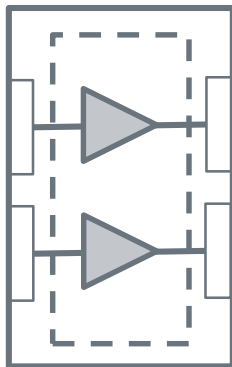
- > 25W CW P1 dB Output Power
- Broadband operation to 1000 MHz
- 1- 2000 MHz usable range
- 25.5 dB Gain @ 500 MHz
- 13 dB Gain @ 2000 MHz
- 30% DVB-T efficiency at 860MHz
- TO-270 2 lead over-molded plastic package
- Handles >65:1 VSWR with 3dB overdrive
- Advanced integrated ESD protection

Highest RF ruggedness in the industry at rated power level

MRFE6VP6300H: 300W LDMOS transistor for ISM and FM/VHF broadcast applications



- Unmatched Input and Output
- 25 dB gain at 130 MHz
- 80% efficiency at 130 MHz
- Housed in NI-780 air-cavity ceramic package
- Extreme Ruggedness: handles >65:1 VSWR with 3dB overdrive
- Product Longevity Program: guaranteed availability until 2025



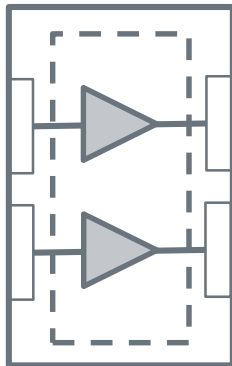
Available Reference Circuits

1. 13.56 MHz (300W CW)
2. 88-108 MHz FM (350W CW)
3. 230 MHz (300W Pulse)
4. 500 MHz (320W CW)
5. 128 MHz (300W CW)

MRFE6VP5600H: 600W LDMOS transistor for ISM and FM/VHF broadcast applications



- Unmatched Input and Output
- 24.6 dB gain at 230 MHz
- 75.2% efficiency at 230 MHz
- Housed in NI-1230 air-cavity ceramic package
- Extreme Ruggedness: handles >65:1 VSWR with 3dB overdrive
- Product Longevity Program: guaranteed availability until 2025



Available Reference Circuits

1. 1.8-30 MHz (1kW CW with 2xMRFE6VP5600H)
2. 50-90 MHz (600W Pulse)
3. 88-108 MHz FM (680W CW)
4. 170-230 MHz VHF (125W DVB-T)
5. 230 MHz (600W Pulse)
6. 225-450 MHz (600W Pulse)
7. 434MHz (600W)
8. 128 MHz (600 W CW)

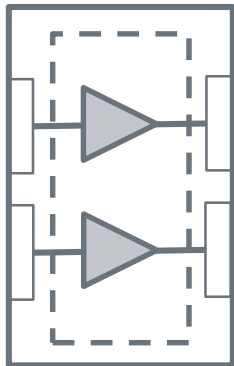
[Datasheet](#)

MRFE6VP61K25H: 1.25kW LDMOS transistor for ISM and FM/VHF broadcast applications



Freescalé's flagship RF transistor

- Unmatched Input and Output
- 22.9 dB gain at 230 MHz CW
- 74.6% efficiency at 230 MHz CW
- Housed in NI-1230 air-cavity ceramic package
- Extreme Ruggedness: handles >65:1 VSWR with 3dB overdrive
- Product Longevity Program: guaranteed availability until 2025



Available Reference Circuits

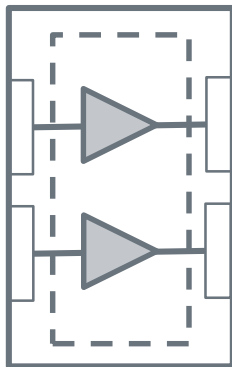
1. 27 MHz (1300W CW)
2. 40 MHz (1300W CW)
3. 60-65 MHz (1250W Pulse)
4. 81.36 MHz (1250W CW)
5. 88-108 MHz FM (1100W CW)
6. 81.36 MHz planar balun (1400W CW)
7. 128 MHz (1250W Pulsed CW)
8. 144 MHz (1250W CW)
9. 175 MHz (1250W CW)
10. 170-230 MHz VHF (225W DVB-T)
11. 230 MHz (1250W Pulse)
12. 352 MHz (1250W Pulse)
13. 500 MHz (1000W CW)

[Datasheet](#)

MRFE6VP5300N: 300W plastic LDMOS transistor for all applications below 600 MHz



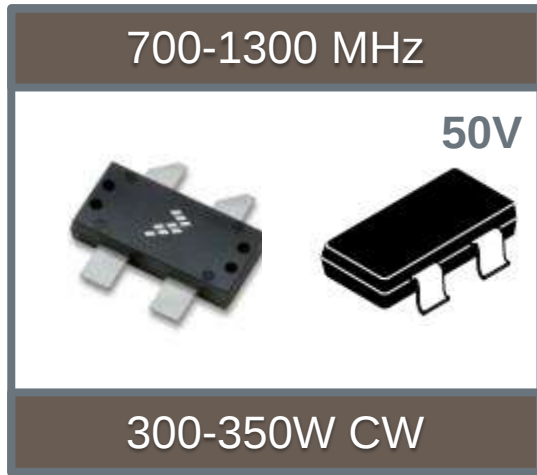
- Unmatched Input and Output
- 25 dB gain at 230 MHz CW
- 70% efficiency at 230 MHz CW
- Housed in TO-270WB over-molded plastic package
- Extreme Ruggedness: handles $>65:1$ VSWR with 3dB overdrive



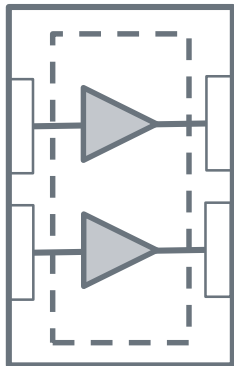
Planned Reference Circuits

- 88-108 FM (300W CW)

MRF8VP13350N: 300-350W LDMOS transistor for ISM applications 915 and 1300 MHz



- Unmatched Input and Output
- 300W at 1300 MHz, 350W at 915 MHz
- Housed in OM-780 over-molded plastic package
- 10:1 VSWR



Planned Reference Circuits

- 900 MHz (350W)
- 1300 MHz (300W)

Competitive Advantage: Reference Designs

MRFE6VP61K25H: One part /many customized reference designs



MRFE6VP61K25H/S
delivers 1250W CW
or Pulse from 1.8
MHz to over 600 MHz

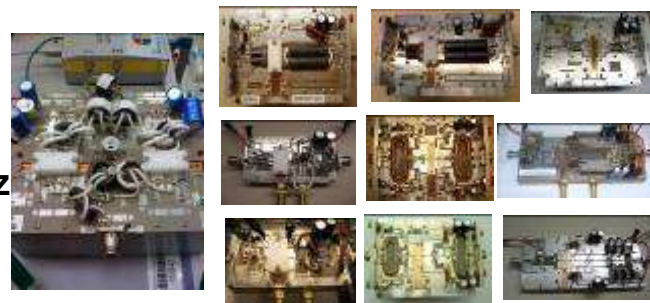
Industrial

MRI 128 MHz, 20-120 MHz

Synchrotron 352 MHz, 500 MHz

Laser exciter 81 MHz

Plasma generator 100MHz, 130 MHz



Aerospace

Weather radar 27.5, 450 MHz

HF Comms 2-30MHz



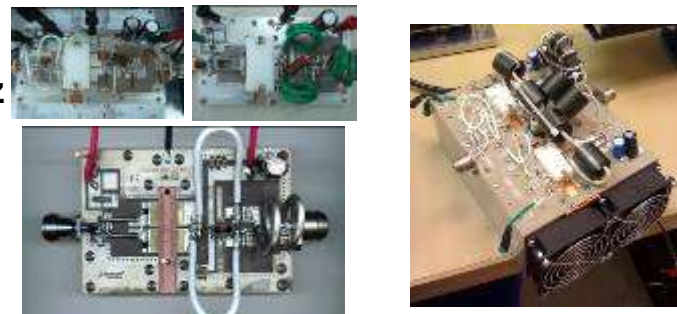
Broadcast

Shortwave radio 1.8-30 MHz

Band I TV 45-90 MHz

FM 87.5-108 MHz

VHF TV/DAB 170-230 MHz



Freescal e Wideband Designs

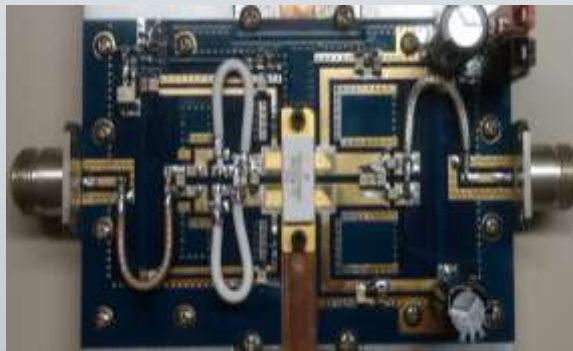
MRFE6VP100H 30-512 MHz

- Broadband operation 30 to 512 MHz
- > 16dB Gain , 50% typ efficiency
- > 100W CW P1 dB Output
- Simple matching



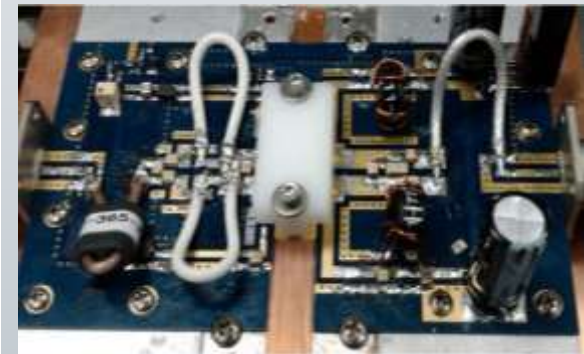
MRFE6VP100H 400-1000 MHz

- Broadband operation 400 to 1000 MHz
- >14dB gain, >40% Efficiency
- > 100W CW P1 dB Output
- Simple matching



MRFE6VP100H 136-941 MHz

- Broadband operation 136 to 941 MHz
- >13dB gain, >30% Efficiency
- > 100W CW P1 dB Output
- Simple matching



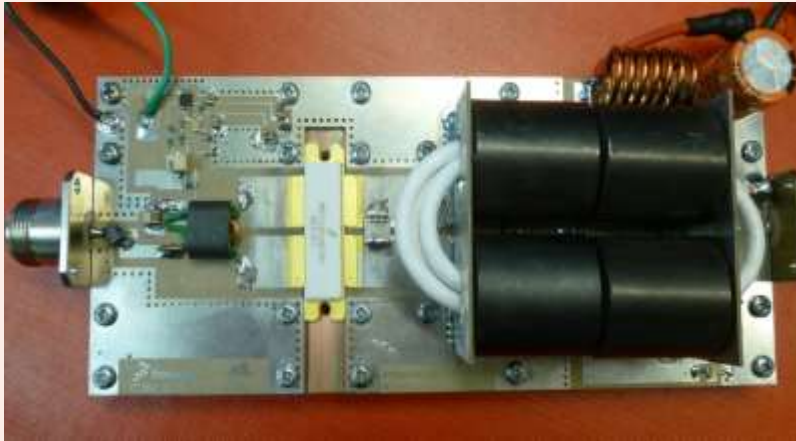
MRFE6VP61K25H 27 MHz Application

MRFE6VP61K25H 27 MHz

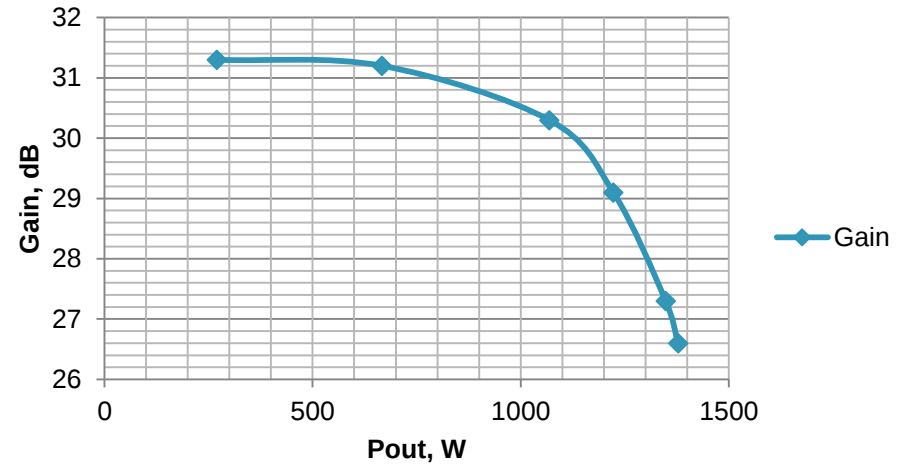
VDS: 50 V, Idq: 150 mA

Pout > 1300 W CW

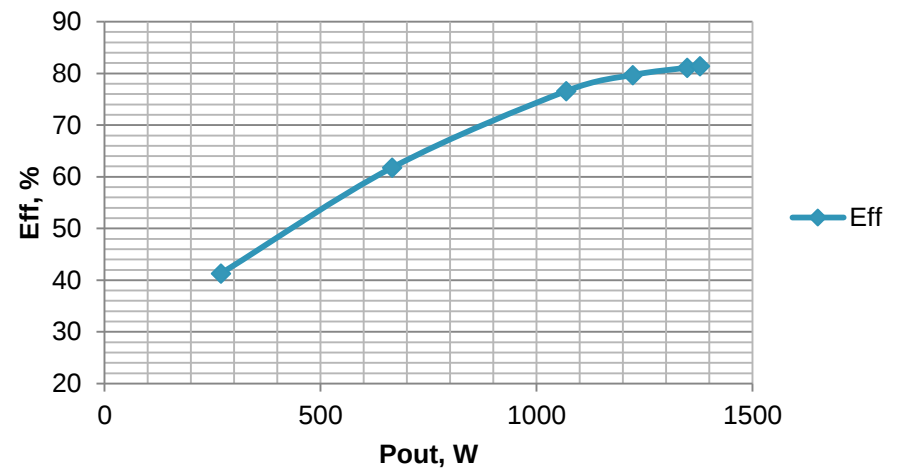
Eff > 80%



61K25 27 MHz Performance



61K25 27 MHz Performance



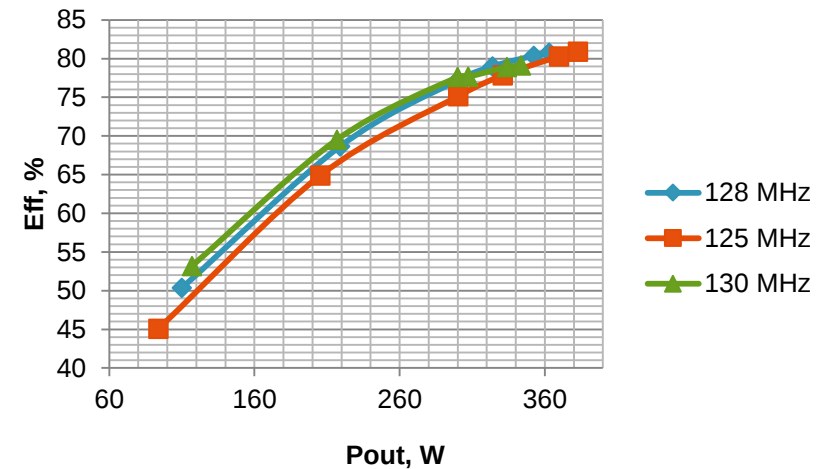
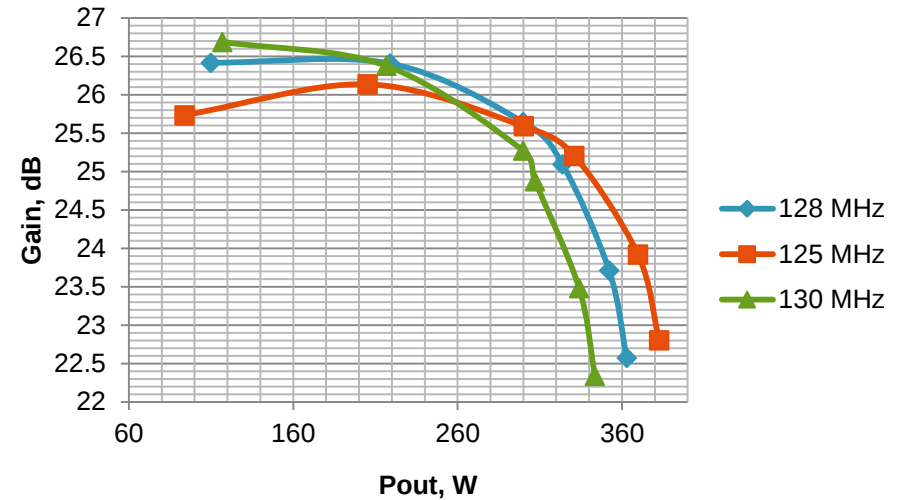
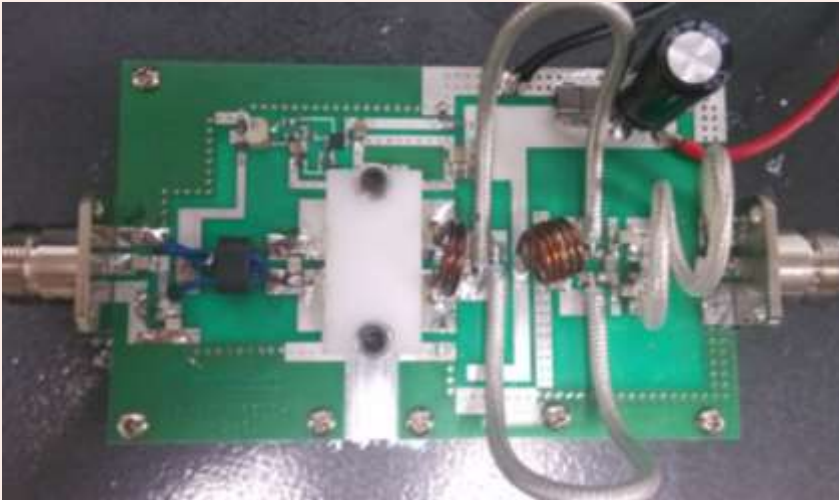
Freescal 128 MHz MRI Solutions

MRFE6VP6300H 128 MHz

VDS: 48 V, Idq: 150 mA

300 W CW

Eff > 75% from 125-130 MHz



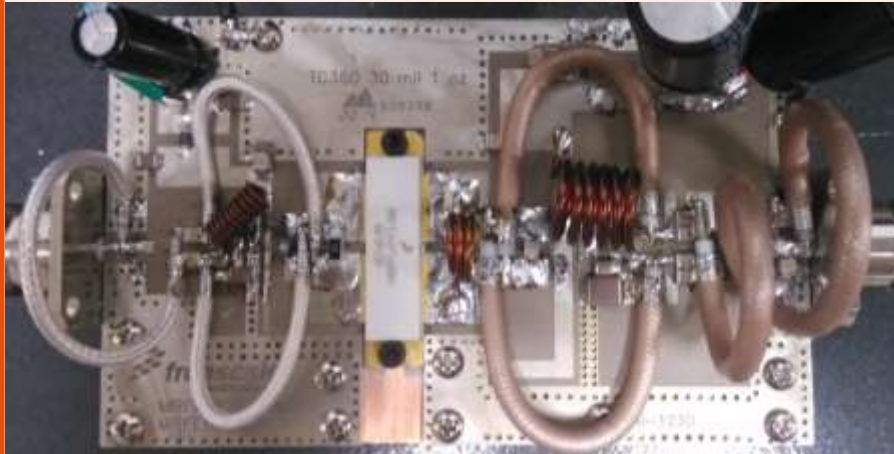
Freescal 128 MHz MRI Solutions

MRFE6VP5600H 128 MHz

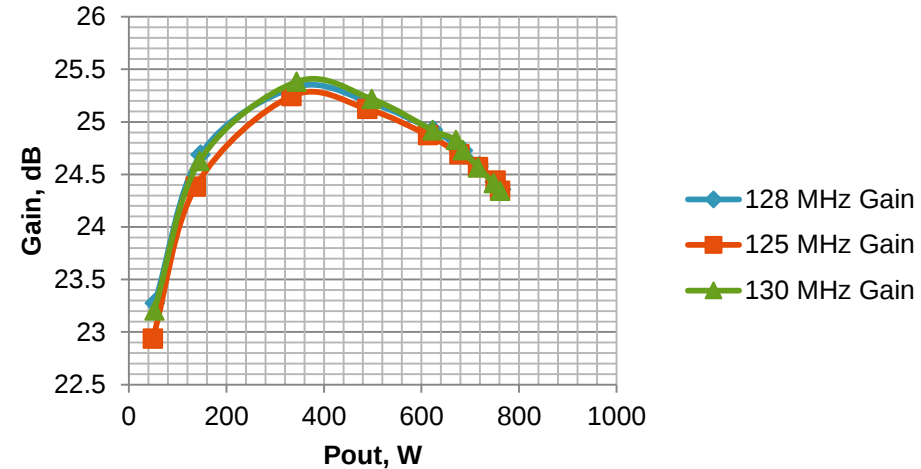
VDS: 48 V, Idq: 150 mA

760 W CW

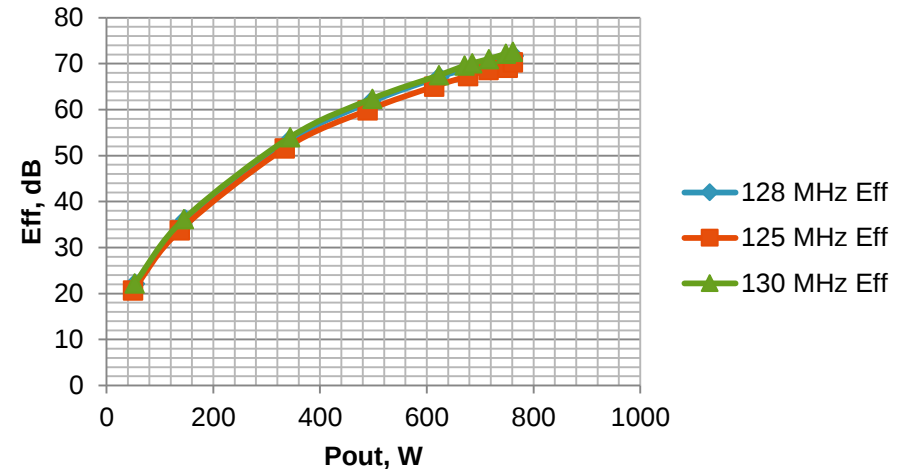
Eff > 70% from 125-130 MHz



5600 128 MHz Gain



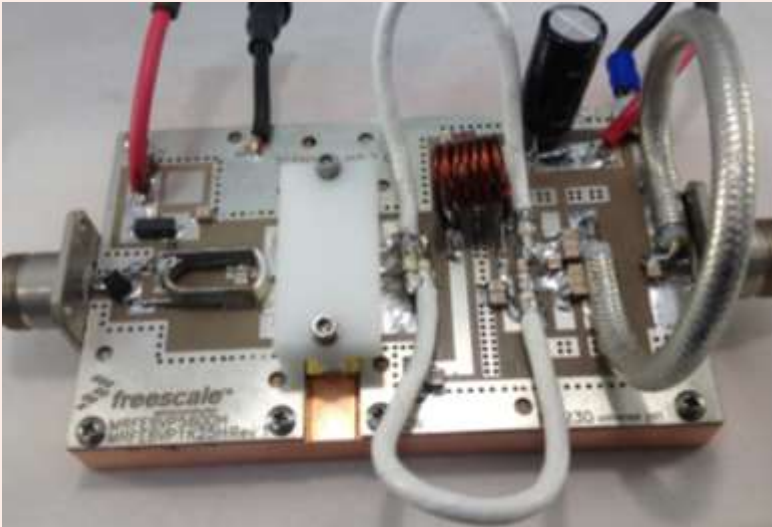
5600 128 MHz Eff



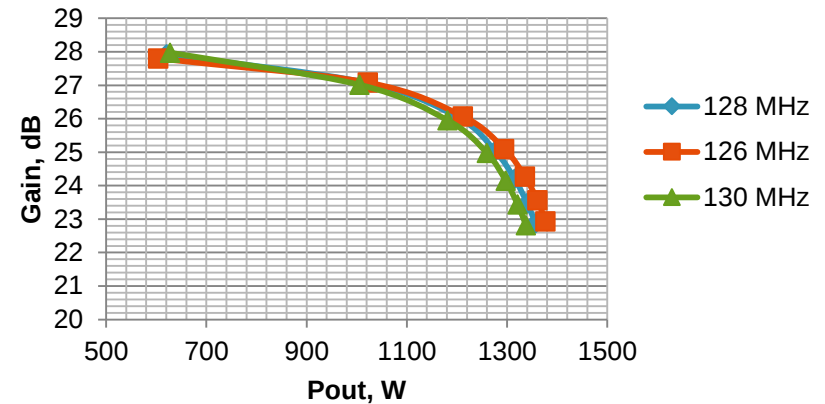
Freescal 128 MHz MRI Solutions

MRFE6VP61K25H 128 MHz

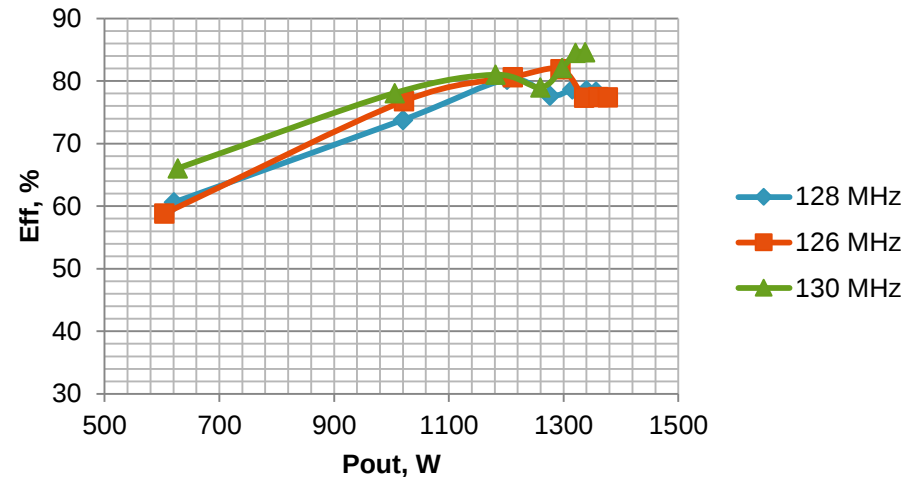
- $P_{out} \geq 1200W$
- Pulsed CW 10 ms, 10% duty cycle
- $Eff > 73\%$ from 126-130 MHz



61K25 128 MHz Pulsed CW



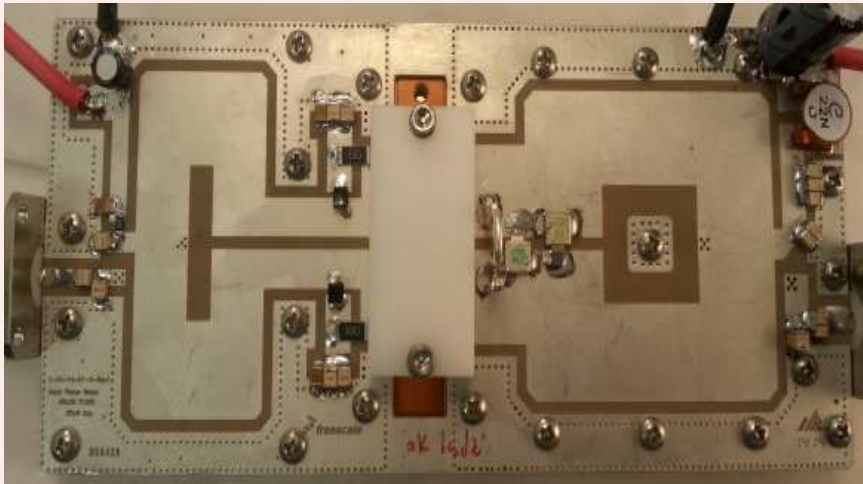
61K25 128 MHz Pulsed CW



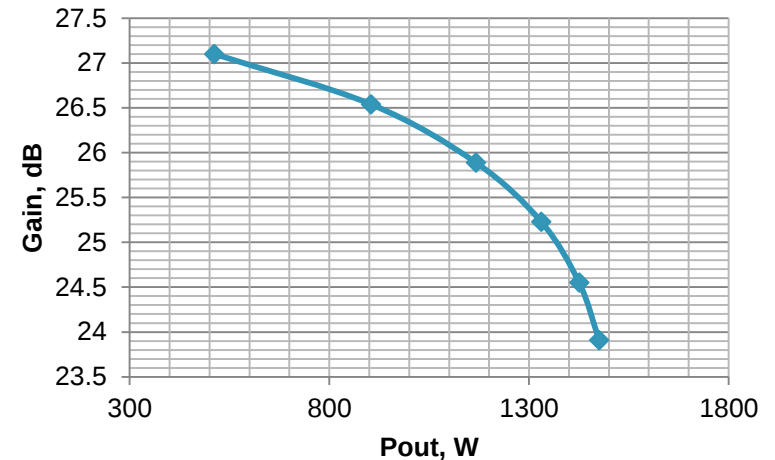
Freescall 61K25H 81.36 MHz Planar Balun Solution

MRFE6VP61K25H 81 MHz

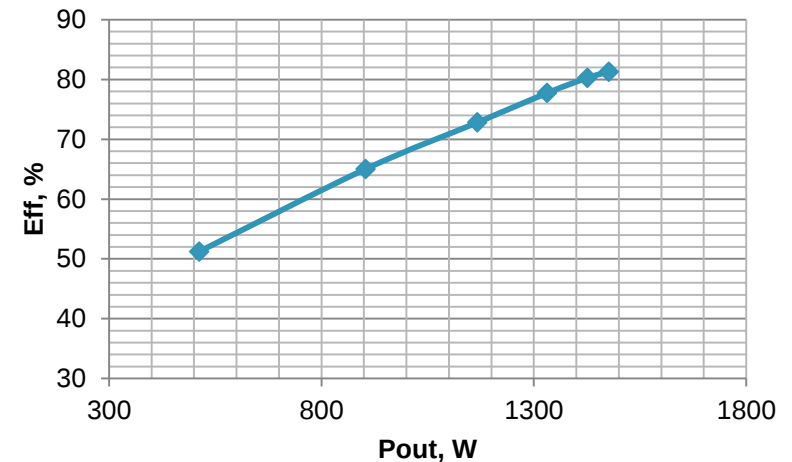
- VDD = 50 V, CW signal
- 10:1 Planar Balun, easy for mass production
- Gain ≥ 23.5 dB Typical
- Pout ≥ 1400 W
- Efficiency ≥ 80 %
- IRL = -10 dB or better



61k25 81.36 MHz



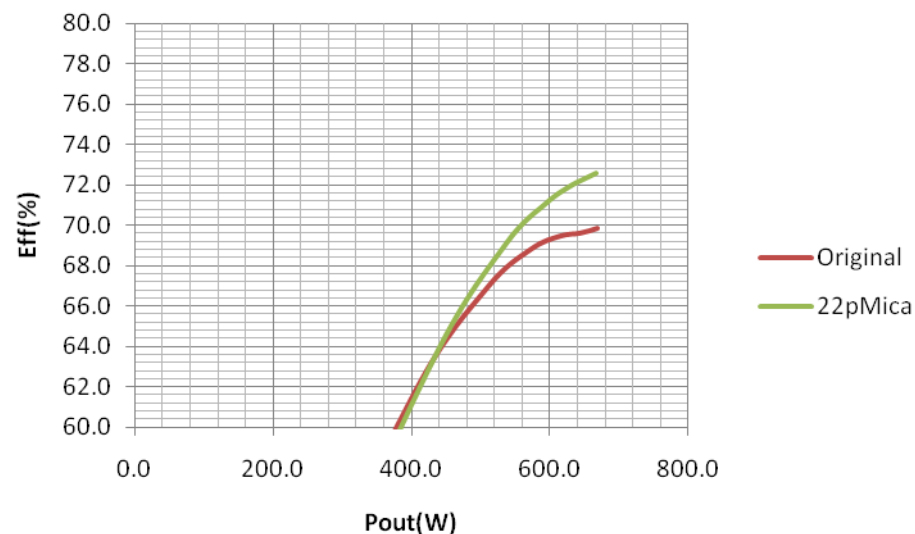
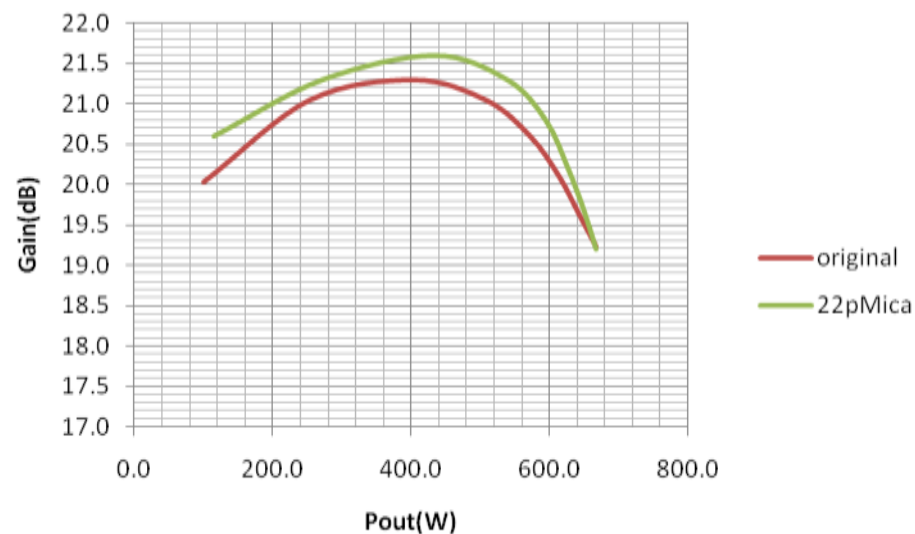
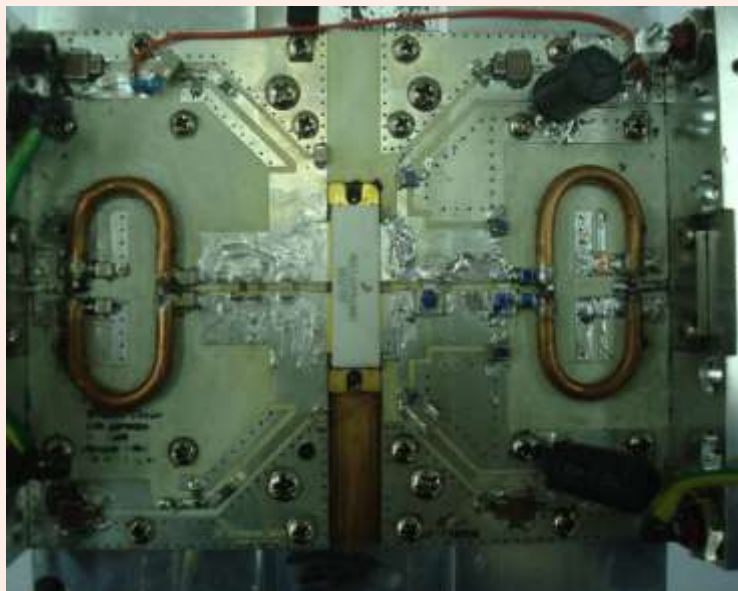
61k25 81.36 MHz



Freescall 650MHz Synchrotron Solutions

MRFE6VP8600H Single Device

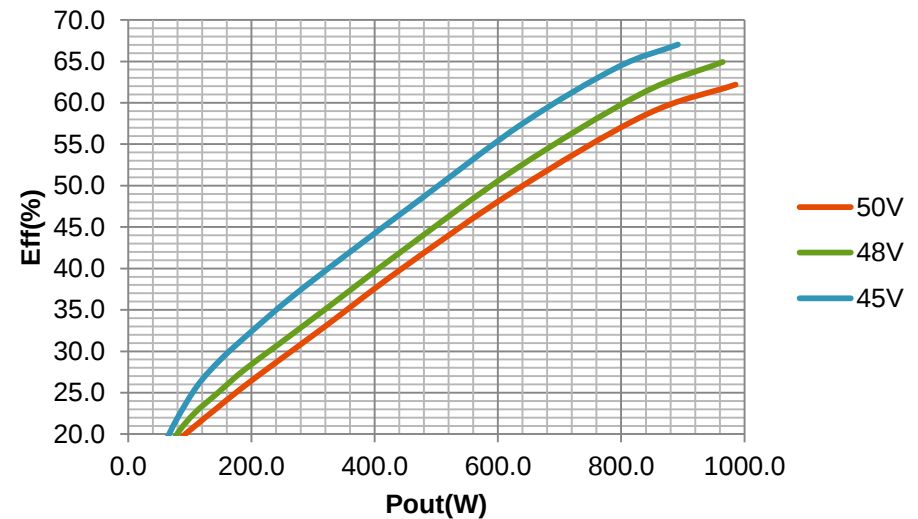
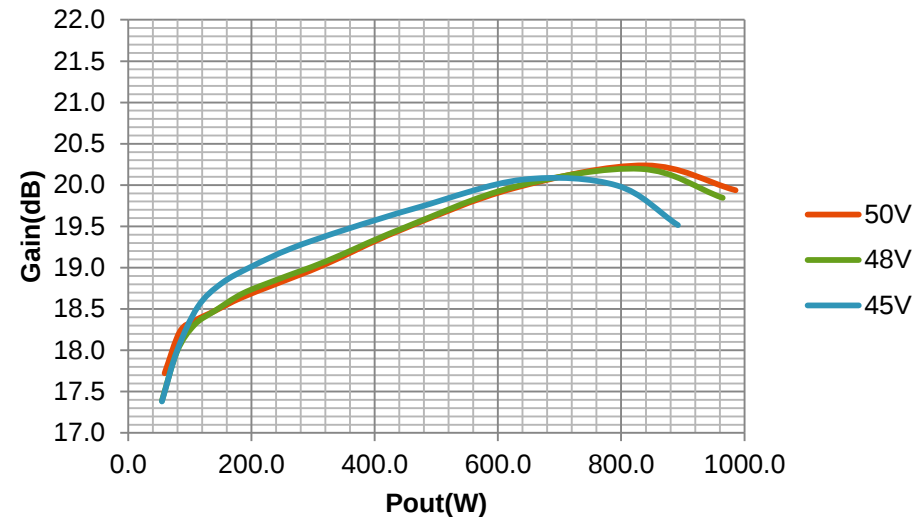
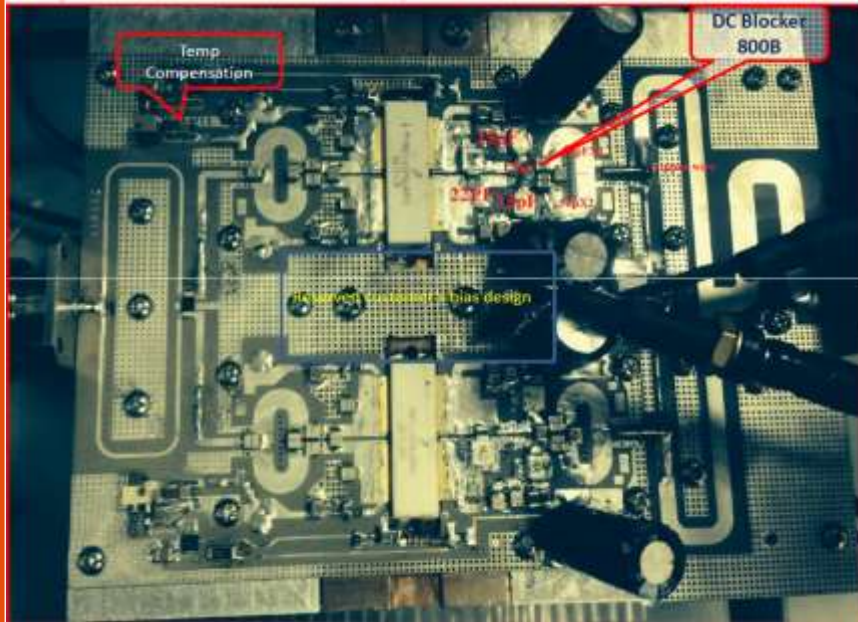
- VDS: 50 V, CW signal
- P1dB= 600 W CW
- Eff > 71% @ 600 W



Freescal 650MHz Synchrotron Solutions

MRFE6VP8600H Dual Device

- VDS: 48 V, CW signal
- Output Power: >950W
- Eff : 65% @ 950 W



We are Available at

- Bill Zheng bill.zheng@freescale.com
- Song Di song.di@freescale.com
- Tiefeng Shi tiefeng.shi@freescale.com
- Kaldi Li kaldi.li@freescale.com
- Davie Bai davie.bai@freescale.com



www.Freescale.com